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ABSTRACT

A computer-assisted instruction (CAI) project focused primarily on curriculum development in three technical areas: science, mathematics, and communication skills. The project also sought 1) to develop specific course material and methods of presentation; 2) to provide explanations of various techniques and strategies for dealing with course development, with emphasis on the education of vocational education teachers; 3) to evaluate and articulate the combination of CAI with other educational strategies, and 4) by means of careful experimentation, to determine optimum formats for vocational-technical material taught with computer assistance. The four-year project used first an IBM 1410 computer and then an IBM 1500; programs were in the COURSEWRITER language. In this report the curriculum material in mathematics, spelling, engineering science, testing, and occupational guidance are presented in some detail, along with the systems programs for display and coding, research studies into educational strategies and equipment evaluation, and the flowcharts developed by the project. The dissemination activities of the project are summarized. (JY)

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THE PENNSYLVANIA STATE UNIVERSITY · UNIVERSITY PARK, PA.

EXPERIMENTATION WITH COMPUTER-ASSISTED INSTRUCTION IN VOCATIONAL-TECHNICAL EDUCATION

FINAL REPORT

February, 1971

Report No. R-37

EM 009 638

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The Pennsylvania State University

Computer Assisted Instruction Laboratory
University Park, Pennsylvania

Final Report

EXPERIMENTATION WITH COMPUTER-ASSISTED INSTRUCTION IN VOCATIONAL-TECHNICAL EDUCATION

1965-1970

U. S. O. E. Project No. 5-85-074

Harold E. Mitzel
Principal Investigator

February, 1971

Report No. R-37

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CHAPTER I

INTRODUCTION

Focus of Project

The computer-assisted instruction project focused primarily on curriculum development in three technical areas: science, mathematics, and communication skills. Course development was deemed to be such a crucial area of investigation because the capabilities of computer-assisted instruction have frequently been limited simply because of the lack of available "software." The project sought to develop specific course material and methods of presentation as well as providing explanations of various techniques and strategies for dealing with course development.

There was an emphasis on the education of vocational education teachers. The project sought to explore the promising strength of CAI in the rapid preparation of vocational-technical teachers. Venn points to the cruciality of university leadership in this task:

> . . .the expansion and improvement of vocational and technical education are heavily dependent on some resolution of the teacher-training question. This cannot and will not happen through the efforts of people already in the field; higher education in particular must assume leadership in the preparation of vocational and technical teachers. (Venn, 1964, p. 36.)

Secondly, the project attempted the evaluation and articulation of computer-assisted instruction with other educational strategies, and, by means of careful experimentation, determined optimum formats for vocational-technical material taught with computer assistance. This application on an interdisciplinary basis is advocated by Brandon and Evans:

> Briefly, the broad nature of research results and research techniques at the present time in the various disciplines and fields of application show interesting and profitable avenues for our exploration and study:
>
> 1. New methods of teaching and learning through many new media, numerous 'synthetics,' programed learning, computer-based instruction, etc. Many aspects of so-called 'related instruction' in vocational education are uniquely adaptable to these media. (Brandon and Evans, 1965.)

The President's Panel on Vocational Education (1962) advocated that eight out of ten of the twenty-six million young people who started, or who will start, work during the past decade (1960-1970) would have gained occupational competence through vocational-technical education. To this massive challenge must be added the extensive retraining needs of hundreds of thousands of adult workers who are presently underemployed or who have been automated or mechanized out of productive employment.

Third, the curriculum development effort was accompanied by coordinated research and evaluation. Careful experimentation with CAI materials in naturalistic settings were required in order that the worth of the innovations represented by the new approach to vocational education might be ascertained prior to widespread investment in equipment and curriculum change. For this reason, a closely articulated research effort was designed and included in the overall research program plan for the Computer Assisted Instruction Laboratory.

Fourth, the training and dissemination programs within the Lab's activities were designed to supplement and balance the research and development activities. The severe national shortage of curriculum and research specialists in vocational-technical education has been traditional; it is now critical. The fellowships, graduate assistantships and summer workshops included in the Laboratory's program were designed to help alleviate this shortage. With respect to dissemination, it is clear that innovations in education do not just happen. New methodologies, new curricula, and new educational strategies must be invented and communicated through as many avenues as possible in order to overcome the great inertia in educational processes. Thus, the CAI Lab's staff believed it as important to disseminate cogent information concerning its activities and progress as it was to perform continuing research and development.

The research and development program was planned as a four-year effort with a careful build-up of equipment and personnel during the initial year of operation. The work of the project was carried on by an organization of two professional teams, one focused on the preparation of teaching materials in vocational-technical subjects, and a second seeking answers to questions about computer-assisted instruction by means of basic and applied research. About twenty computer-presented instructional units were prepared and tested by the staff. These materials could be integrated into prototypes of vocational-technical education programs. In addition, the Lab carried on a variety of training and dissemination activities designed to communicate the innovation of computer-assisted instruction to the public and the professions.

Funding of the Project

The project was conducted at Penn State University between July 1, 1965 and December 31, 1969. Funds were provided by the United States Office of Education on the following schedule:

1964-65 (1 mo. only)	-	$ 7,236
1965-66		162,521
1966-67	-	310,001
1967-68	-	206,000
1968-69	-	273,130
Total	-	$958,888

Themes in Computer Assisted Instruction

Research and development involving the use of a computer to assist in the instructional process may be thought of as being related to teaching machine technology, but CAI, because of its flexibility, decision logic characteristics, and sophistication of input-output mode, must be considered as a quantum advance over traditional programed instruction. Projects using a computer for instruction are similar to each other, but differ in their emphasis. The flexibility of the digital computer allows for a variety of themes different from and richer than the themes of programed instruction as represented in the programed text or simple teaching machine. One such theme is *the extent to which input and output displays facilitate communication between the student and the computer*, e.g., cathode ray tube display, various large capacity random access visual and audio devices, special response keyboards, light pens, etc. Multi-media interfaces between learner and computer seem to be necessary with reluctant learners and the handicapped and they seem to be required for teaching complex material such as the teaching of reading. Good display and response devices are particularly attractive to the researcher concerned with instruction, but at the same time handmade interface equipment does not stimulate research in other laboratories because the special equipment is generally of experimental or prototype construction and extremely expensive. Two efforts that emphasize this theme in computer aided instruction are those of Bitzer and Easley (1964), and Suppes and Ginsberg (1962).

A second theme is to adapt course organization to individual student's needs; here the concept is to monitor and analyze student performance, and, on the basis of this performance plus other historical information about the individual student, continually adjust the course organization to optimize it for every particular student's progress. Such tailoring of materials to an individual student is highly desirable, but in the occupational area adequate tailoring to the student history is difficult. Tailoring to long-term performance of a student is possible, but of relative high cost because considerable computer capability would be needed for each student. To some extent, this is the approach of Stolurow and David (1963), and Smallwood (1962).

A third theme is that of tutorial interaction; the concept is that the high speed logic of the computing machine reacts to the detailed features of student performance on specific tasks, observes the efforts of the student in dealing with these tasks, and presents appropriate remedial or accelerated action where the student is not succeeding or is insufficiently challenged. The tutorial interaction is supplementary to the strategic job of adjusting the arrangement and difficulty of the tasks and their manner of presentation to the individual student. This approach is exemplified by the effort at IBM's T. J. Watson Research Center by Utall (1961).

A fourth theme is the process of simulation and gaming between the student and the machine; here the role of the machine is that of simulator of a process or as an opponent with which the student interacts, just as he interacts with process or persons in laboratories or real situations. This theme is prominent in the work of Feuerzeig (1964), at Bolt, Beranek, and Newman, Inc., and Wing (1966), at the Board of Cooperative Educational Services, Westchester County, N. Y. Public Schools (Swets, 1962).

The present project in computer-assisted instruction emphasized tutorial interaction, and made limited use of the other themes described. We believe that each of the emphases described above represents a valid conception of an approach to the use of computers as educational aids, but that the approach we have selected is an appropriate one for education, to the extent that the research and development commitment is pointed toward partial solutions of immediate problems as well as to those of a long-term nature. Current and projected needs force administrators to consider instructional cost, both for the development of courses, and the administration of these courses by the computer in "production" teaching. This research established a flexible interface between the learner and the computer, but at the same time it utilized a system that is justifiably economical in the long run to allow for wide-scale adaptation to a variety of educational operations.

We prepared the instructional materials in the present project in the same manner that we used for developing four college courses under a previous contract with the U. S. Office of Education. Unlike most developmental projects in CAI, we have not devoted resources to the invention of terminal hardware or to the writing of computer programs in machine language. We avoided these tasks by using a commercially available typewriter terminal as the interface between the computer and the student, and using the Coursewriter program developed at the IBM T. J. Watson Research Center for controlling this interchange. Virtually all of our resources were devoted to the preparation of the educational materials presented by the computer since it appears that a major limiting factor in the ultimate wide-scale use of computers as an educational aid will be the time necessary to prepare the educational materials.

The course development under this contract was an eclectic one in which current theory, practice of teaching, and programed instruction were adapted and assimilated to the preparation of these courses rather than trying to prepare materials based more directly on current learning theory developed in the learning laboratory. This approach appears to have resulted in efficient preparation of materials that teach well, and materials suitable for theoretical learning studies. This eclectic approach, coupled with a concentration of resources in course development, made it possible to prepare an extensive set of post-secondary course materials designed specifically for computer presentation. However, we must admit that improved hardware has made a good portion of our course materials obsolete.

Objectives of the Project

The Computer Assisted Instruction Lab at Penn State sought to achieve a wide variety of curriculum development, research, training, and dissemination objectives. Accordingly, the specific objectives were organized under the four headings.

Curriculum Development Objective. The curriculum development objective was to prepare curriculum material for computer presentation of selected technical-vocational subjects suitable for youth and adults in the first two years of post-high school education.

Research Objectives. The research objectives were 1) to evaluate the results achieved in student programs employing CAI and the articulation of CAI with other components of instructional systems; 2) to evaluate by means of experimentation, fundamental research questions within CAI, topics dealing with the effectiveness of different forms of knowledge of results--for example, optimal post-feedback intervals, social and motivational components in knowledge of results, and relationship of typing skill to learning and retention; and 3) to study the feasibility of adapting a wide variety of vocational education teaching material to CAI modes of presentation and to make recommendations to appropriate federal and state educational agencies for future feasibility, field testing, demonstration, and pilot experimentation.

Training Objectives. The training objectives were 1) to train an interdisciplinary group of research fellows as vocational educational curriculum research specialists to the level of the doctoral degree; and 2) to train through summer workshops a group of vocational educational educational subject matter specialists in course writing for computer-assisted instruction.

Dissemination Objectives. The dissemination objectives were to disseminate the results of CAI research development to school systems, colleges, and governmental agencies, making available CAI materials and know-how in the form of reports, journal articles, "hands-on" demonstrations, conferences, talks, computer programs, video tapes, films, and television programs.

It was possible for the investigators to achieve a coordinated and integrated approach to the wide variety of activities and study that needed to be pursued as shown in the objectives above.

CHAPTER II

CAI AT PENN STATE

What is CAI

Through the use of a computer in which a course is programed and stored, the student can receive instruction which is individually paced and presented. This instruction may be tutorial in nature, be a problem simulation, consist of drill and practice, present information, or be a combination of all four types. The course materials for tutorial computer-assisted instruction are stored in the computer, and the information is presented to students at special computer connected instruction stations.

Two computer systems were used during the project. An IBM 1410 system was used from 1965-1967 and the IBM 1500 system was used from 1967-1969. For a period of several months, there was an overlap of the systems. For a more complete description, see Chapter III.

An important aspect of computer-assisted instruction is the speed at which the computer presents information to the students taking the course. In a time-sharing situation, the individual student feels that the computer is presenting only his lesson even though other students are taking the same course or other courses at the same time. This time-sharing is possible because the computer reacts in microseconds while a student reacts in terms of seconds or even minutes.

In using the computer for instruction purposes, questions can be presented by the computer; the student can respond by using the typewriter keyboard attached to a cathode-ray tube (CRT). In addition, on instructional stations which incorporate a CRT, it is possible to have the student use a light pen to respond to questions. The student presses the light pen against his answer choice; the light sensitive pen receives the light and the position of his choice is recorded. Responses from the keyboard or light pen can then be analyzed by the computer, and the student may be given feedback corresponding to the response made. An audio unit allows the student to record responses which may be analyzed by the instructor after the student has signed off the course.

Since the computer has the capability to record and recall student responses, the number of correct answers, the number of wrong answers, etc., the sequence of instruction for a particular student can be altered on the basis of his response history. More challenging material or remedial instruction can be presented on the basis of past performance, or sections of the course may be skipped if the student's performance is at a specific level of proficiency. And if the student stops interacting with the computer for a period of time while taking a course, when he signs on again, instruction will resume where he stopped previously.

The computer can be used to record a variety of types of information for all students, e.g., the exact contents of his response, the number of seconds he takes to respond, and his exact position in a course. Summary information such as number of correct responses to a question, total number of response attempts, etc., may be produced for analysis by the instructor thereby reducing the teacher's clerical duties and freeing him to give individual instruction.

The nature of the computer input is such that it will accept course content in two ways: 1) course statements may be punched on cards, or 2) course material may be input directly into the computer from the instructional station keyboard. Using the second method, the contents of a course can be replaced, corrected, or deleted easily and quickly by special author commands.

Coursewriter I and II

At the beginning of the project, the developed courses were written in the CAI author language known as Coursewriter I for use with the IBM 1410 computer system. A complete description of Coursewriter I is beyond the scope of this report; however, because it is standard IBM language, it is readily available.

The period between January 1, 1968 and June 30, 1968 was a time of transition in hardware in the CAI Lab. A change was made from the IBM 1410 to the IBM 1500, and in author language from Coursewriter I (Yorktown Heights version) to Coursewriter II. Staff efforts during that period went into the completion of experimental studies begun on the typewriter terminal, the translation of carefully selected course material from the old author language into a new, considerably more flexible language, and the development on the part of the staff of new skills and new teaching strategies for the richer learning environment provided by the 1500 system (IBM Corporation, 1968).

Programing Language

To assist in providing an answer to the question as to how instruction strategies are prepared for the computer, the following excerpt from the IBM 1500 Coursewriter II Author's Guide, Part I: Course Planning is included here.

> The Coursewriter language is composed of individual instructions that can be logically separated into five major groups.
>
> Problem presentation
> Presentation sequence control
> Response requests
> Response analysis
> Scorekeeping
>
> The problem presentation instructions are used to mark the beginning of a problem, to type and display instructional material, to play audio messages, and to project images from film reels.
>
> The response request instructions enter and process student responses from the light pen and from the typewriter and instructional display keyboards. They also record audio messages, control the time allowed for responses and cause performance records to be written automatically (if the author has specified them).
>
> The response analysis instructions determine whether a response is correct, incorrect, or unrecognizable. Special programming is built into the system to handle matching of responses automatically.
>
> The scorekeeping instructions permit the author to channel into performance records the counts of a student's correct answers, wrong answers, time-outs, etc., and to post other special indicative information. They also permit the author to "capture" actual responses and work with them by executing special routines during answer processing.
>
> The presentation sequence control instructions allow the author to provide several paths of instruction based on conditions that arise while students are actually taking the course. They also allow the author to link course segments as needed to complete course flow through an instructional session. (IBM Corporation, 1967, p. 25.)

Course programing languages other than Coursewriter II provide instructions to carry out similar action. With systems dedicated to computer assisted instruction, changes and additions can be made in the programing language. Functions can be written to provide special processing not included as part of the programing language, and these functions can be accessed within the course. Thus, a great deal of flexibility is provided.

Flowcharting

Flowcharting is a means of presenting a course description so that it is easy to visualize and follow. Simple geometric figures are used to show the flow of the course through which a student may pass. A flowchart may be used while a course is being developed to experiment with the sequence of presentation or may be used as a means of communication between the curriculum specialist or course author and a programer. Flowcharts can depict major logical steps or any degree of detail desired and are commonly used as a means of documenting a program. An over-all course flowhcart would indicate general steps without much detail; whereas a detailed program flowchart is a map of the program. A program flowchart should be labeled so that the associated instructions from the programing language are referenced; thus, understandings and modifications of the course are both facilitated.

Flowcharting symbols used in this project were generally consistent with IBM flowcharting symbols. Since programing for computer-assisted instruction is different from programing for other purposes, the meanings of some symbols were altered to fit our particular situations. For example, in flowcharting CAI programs, a few symbols were adapted from those usually used only for flowcharting symbols. The symbols used for flowcharting in this project all appear on the Standard Register Business Forms flowchart template.

Figure 1, page 11, is an example of a flowchart of the type used in the project. This is such a critical area in programing that the strategies developed will be briefly described. Briefly, it is the computer operation, programed by the course author, which moves the student to remedial or advanced work. It allows the author, via the computer, to fit the course to the student. In the diagram shown in Figure 1, the student may choose three routes. He may elect to take a quiz, receive feedback on the adequacy of his knowledge, and then move to the beginning or end of the course. He can also receive instruction, move to a review, and then take the quiz. His third choice would be to go directly to the review, then to the quiz, instruction, or to another review.

Additional flowcharts for specific instructional strategies can be found on page 107 of this report.

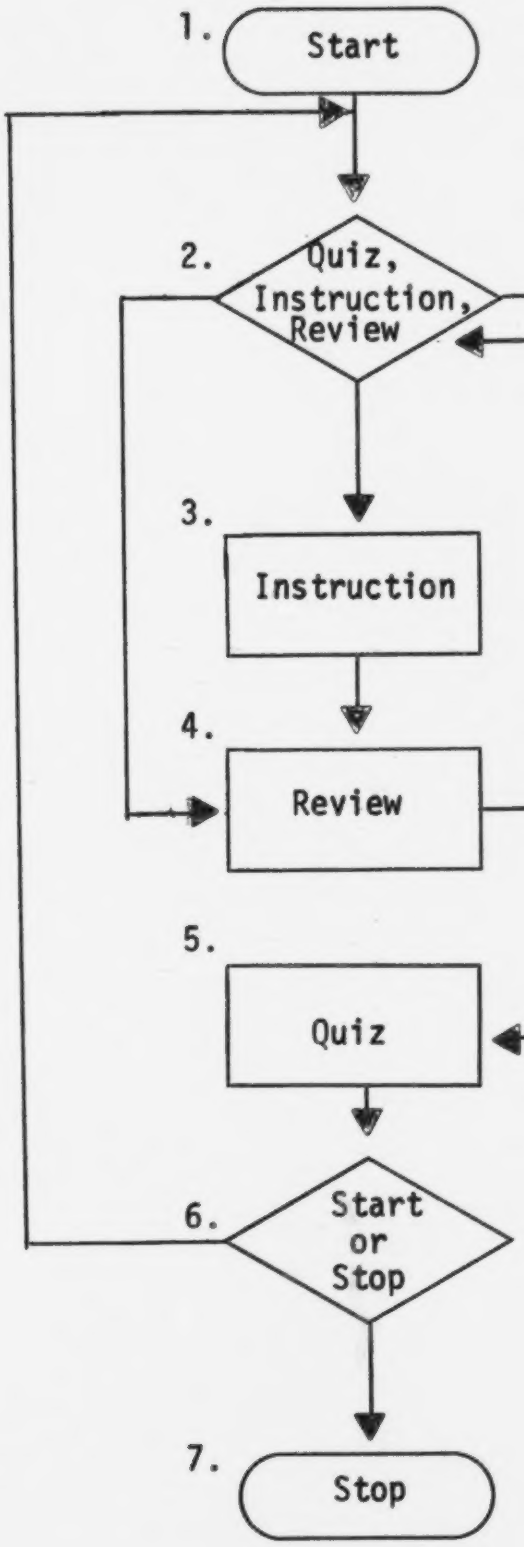

1.
Start
2.
Quiz, Instruction, Review
3.
Instruction
4.
Review
5.
Quiz
6.
Start or Stop
7.
Stop

Fig. 1. Example of a flowchart of the type used in the CAI project.

CHAPTER III

THE DEVELOPMENT OF HARDWARE AND FACILITIES

Physical Facilities

To initiate the vocational-technical CAI project, a large room, 45 feet by 45 feet, was remodeled and the space was designed to accommodate approximately ten professional staff members, eight graduate assistants, five CAI technicians, and four student terminals, each with audio-visual components and a printing desk calculator. From its own resources, the University made available new office furniture and equipment and installed air conditioning and electrical controls in the space occupied by the heat-generating terminals.

Equipment Evaluation

In July, 1965, two student terminals in the CAI Lab were connected by means of dedicated long distance telephone lines to the IBM 7010-1448 computer configuration at the T. J. Watson Research Center, IBM Corporation, Yorktown Heights, New York. The Lab was under contract for this service until June 30, 1966. The service included not only 64 hours of terminal time weekly, but compiled course listings and summarized student records taken from log magnetic tapes.

Delivery of four new IBM 1050 communications terminals with improved audio-visual components, expected in October, 1966, was delayed. Installation of this equipment, replacing the two "bench-built" units, occurred in January, 1967. Orders were placed for the additional four terminals to be installed in Williamsport and in Altoona by July, 1967.

By June, 1966, the project was almost completely moved into its new remodeled quarters. The new facility was extremely well suited to the needs of the project and staff. Four new student terminals were installed in four separate sound-proofed and air-conditioned rooms. The Laboratory office space completely accommodated the staff of the project.

By July, 1966, conversion to Penn State's own 1410 computer system had been completed, and CAI courses prepared to date operated successfully on this system. The new system controlled four student terminals in the Laboratory, two additional terminals located at the Williamsport Area Community College, and two terminals on Penn State's Commonwealth Campus in Altoona. The four student terminals in the field were installed and available for student instruction by mid-July, 1966. Students enrolled at these two schools were used for research and evaluation of the CAI courses in technical education during the summer, 1966. The schematic in Figure 2 shows this geographic arrangement of equipment.

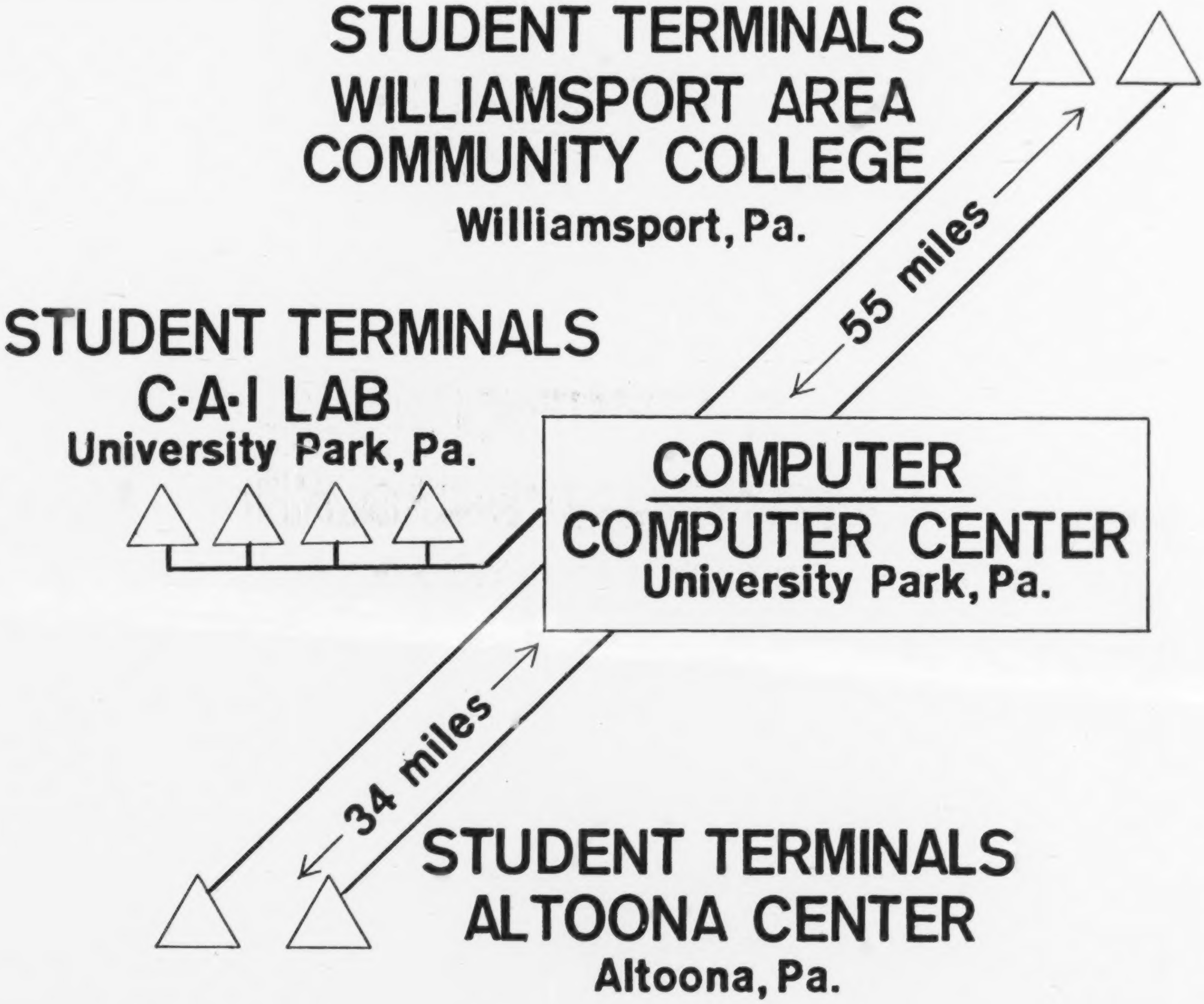

STUDENT TERMINALS
WILLIAMSPORT AREA
COMMUNITY COLLEGE
Williamsport, Pa.
55 miles
STUDENT TERMINALS
C·A·I LAB
University Park, Pa.
COMPUTER
COMPUTER CENTER
University Park, Pa.
34 miles
STUDENT TERMINALS
ALTOONA CENTER
Altoona, Pa.

Fig. 2. Schematic showing geographic arrangement of CAI student terminals.

The research and development progress in CAI completed up to December 31, 1967, was accomplished on a hardware configuration organized around an IBM 1410 computer as a central processor used in time-sharing mode and located in Penn State's Computation Center. Connected to the central processor by telephone lines, the CAI Lab maintained eight student stations consisting of IBM 1050 typewriters, each augmented by a random access tape recorder and a random access slide projector. This modified business application equipment provided service as has been described for two and one-half years, but was replaced late in December, 1967 with an eight terminal IBM 1500 instructional system. The new system, designed for instructional purposes, offered numerous advantages over the former. Displays of materials are achieved almost instantaneously on the CRT terminal instead of the tedious typewriter type-out. Student's answer processing was vastly improved. Last, but not least, the cost per student terminal hour was about one-fourth of the former 1410/1050 system.

During the first half of 1968, the project staff was primarily engaged in the translation of experimental course materials from Coursewriter I, the author language of the IBM 1410 system, to Coursewriter II, the author language of the IBM 1500 system. In addition, the Lab learned the intricacies of the new hardware/software configuration and developed new dictionaries and "macros." Studies were initiated during the period which built upon what they already learned about response modes, sequencing, and student attitudes.

Due to budget cuts for the 1968-69 fiscal year, the Lab reluctantly had to withdraw the terminals from Williamsport and Altoona. Both institutions had provided us with unstinting cooperation in the selection of technical education students who served as subjects. The faculties of both schools had provided many hours of valuable consultation on curriculum and display problems.

CHAPTER IV

CURRICULUM MATERIALS

Mathematics

Technical Mathematics - (IBM 1410 Computer System)

The technical mathematics curricuiculum (Ritchey, 1965) embodied in this CAI course includes the following topics: graphing, exponents, roots, trigonometry, simultaneous quadratic equations, calculus, logarithms, vector analysis, algebra, ratio, and proportion.

By design the first segments programed are common to both physics and mathematics instruction. The common segments include the metric system, working with units, and significant figures. A summary of the course segments and their content follows:

Basic Mathematics. A review of basic mathematics; course is developed by presentation of square root, cube root, and estimating square root and cube root. Estimated time: 1 hour.

Significant Figures. Instruction in the accuracy of calculations used in scientific experimentation. The student is taught the reasons for limiting the number of digits in the results of his calculations. This version teaches the course by telling the student the reasons for using significant figures, but does not present rules for using significant figures. Estimated time: 90 minutes. (Also programed are three additional experimental versions of significant figures.)

Graphs. Definition of basic terms used in graphing; construction and interpretation of graphs with a physical rather than an algebraic slant. Estimated time: 1 1/2 hours.

Logarithms. Program instructs student in logarithms and the use of logarithms and the use of logarithm functions and working technical programs. Estimated time: 1 1/2 hours.

Trigonometry. A study of the applications of the elementary functions of trigonometry. The student learns to use tables, to interpolate, and to perform mathematical operations with the trigonometric functions. Estimated time: 3 1/2 hours.

Vector Analysis. A segment that teaches factors and the law of cosines and sines.

Simultaneous Equations. A segment on how to solve simultaneous linear equations by algebraic methods. The presentation of the material is developed through substitution, "trial and error," and thence to algebraic substitution. The final method presented is algebraic solution using multiplication and addition. Estimated time: 1 hour.

Algebra. The second part of basic mathematics, a continuation of remedial math. Content: algebra. Estimated time: 45 minutes.

Ratio Proportion. A continuation of basic mathematics. This segment develops ratio and proportion and is the terminating sequential course for the basic mathematics sequence. Estimated time: 1 hour.

Test on ra-, rb-, and re-math segments. Test on the material covered in ra-, rb-, re math segments. Includes test on exponents, roots, algebraic expression, ratios and proportion. Test presented via 2 x 2-inch slides and feedback given for each question. Estimated time: 45 minutes.

Number Systems - (IBM 1410 Computer System)

A program entitled Number Systems (Sands, 1966) was written for the purpose of investigating techniques of developing computerized instructional materials in the area of mathematics. The program consists of approximately 840 Coursewriter statements and takes an estimated 3 hours for a student to complete.

The objectives of this program are as follows:

Main Objective

To have students acquire the ability to convert a number from one number system to another. For example: 231 (base five = _____ (base ten)

Sub-Objectives

To recognize for any symbol in a number its equivelant expression containing a coefficient, base, and exponent; an example of this would be to recognize $2(5^2)$ as the equivalent of the 2 in 231 (base five).

To recognize the correct expanded form of any number; an example of this would be to recognize $4(9^1) + 1(9^0)$ as the equivalent of 41 (base nine).

To recognize the correct numerical expression for a verbal statement. An example of this would be to recognize "20" as equivalent to "two groups of the base in any number system."

The programing strategy used is a slight departure from most of the strategies used with Coursewriter. The major criteria for branching is not the type of error response but in the amount of practice required to achieve mastery within sections of the program. Also, an attempt has been made to keep error rate at a minimum. Students who do make errors are not required to type the correct answer, but are given an explanation of the correct solution and are automatically branched to the next item.

Slide Rule - (IBM 1500 Computer System)

This is a course which provides instruction on the use of a slide rule. The scales discussed are those used for: 1) multiplication (C, D, Cl); 2) squaring and cubing numbers and taking square and cube roots (A, B, k); 3) finding logarithms (L); and 4) reading trigonometric functions (S and T).

Spelling

Two programs in spelling were developed in the CAI Laboratory. Both programs were designed for remedial instruction for high school or post-high school students. The first program described was designed for use on the IBM 1410 computer system. The second program is built for the IBM 1500 computer system and is available for use on the Lab's present computer system. The task of building the second spelling program was facilitated by knowledge gained through the development and testing of the first program.

Communications Skills - Spelling - (IBM 1410 Computer System)

The purpose of the CAI course in communications skills (Bjorkquist, 1965) was to develop and evaluate a computer assisted program of instruction in remedial spelling for students preparing to be technicians. The computer program was planned to diagnose the spelling errors made by individual students and to branch students to remedial programs of instruction appropriate for the types of spelling errors made. It was anticipated that this course would be a prototype for the preparation of other communications materials.

Students completed an orientation which introduced them to the selectric typewriter, tape recorder, and photographic slide outputs of the computer. It also acquainted them with the typewriter they would use for responding and tried to impress upon them the importance of accurate spelling. Instruction in identifying word syllables and in listening for correct pronunciation was included. The orientation was followed by a diagnostic spelling test which identified the types of spelling errors made by the individual. Words in the diagnostic test are pronounced to the student via audio tape message, and he responds by typing the word on the computer typewriter keyboard. Based on an analysis of the responses made by the student, the computer branches those students needing remedial work to one or more of nine remedial programs.

The diagnostic test is made up of words involving nine types of spelling problems: plurals, homonyms, contractions and hyphenated words, words with ie and ei combinations, double consonants, suffixes, e and y endings, words requiring visual discrimination, and "demon" words. A student who misspells a certain percentage of those words involving one of the types of spelling errors is branched to the remedial program of instruction to correct that type of error.

After completion of the remedial program, the student is tested to determine his degree of improvement. Failure to show marked improvement in correcting a type of spelling error will repeat the remedial program for the student.

Words for the diagnostic and remedial programs are selected from graded spelling lists, themes written by students and from words used by technicians in their work. Emphasis is placed on the inclusion of those words which are commonly used by technicians.

Following completion of the orientation, diagnostic test, and remedial programs, the student completes a proofreading exercise. The purpose of this exercise is to test the student's ability to recognize misspelled words in a printed page, to correct errors and to emphasize the importance of proofreading. The program in spelling concludes with a posttest composed of words randomly taken from the same word list as the diagnostic test.

Spelling -
(IBM 1500 Computer System)

This spelling course (Farr, Kelly, and Palmer, 1969) consists of two tests and five instructional segments. The pretest and posttest are parallel in format and in diagnostic structure, but the posttest had twice as many (100) as the pretest. In both of these multiple-choice tests, the student is presented with one sentence at a time. Each sentence contains one blank space to be filled with the word appearing under the sentence. Three possible spellings for that word are shown simultaneously with the sentence, and the student registers his choice of the correct spelling by touching the light pen to the spelling he judges to be correct. The student's choice is then evaluated as correct or incorrect by a computer routine, and wrong choices are recorded in counters. Each student's cumulative totals of wrong responses is available for each of the five error categories being tested. The student does not receive any evaluative feedback about his choices until he has completed the test being taken. However, at the conclusion of both tests, he is informed of the number of errors that he made in each of the five categories.

At the time this course was being developed, audio equipment for the 1500 student stations was not available. And in view of the highly unreliable performance experienced in using tape-recorded spelling tests on the 1410 system, as well as an imminent termination date for the project, we decided to proceed without the use of audio equipment.

Therefore, we represented the possible pronunciations for the three spelling choices with a set of graphic symbols and manipulations. The symbols and manipulations used are modifications of a system for representing sounds which was devised by T. V. Barker of the Lehigh University Speech Department. The major advantage of Barker's system over other graphic systems for representing sounds (e.g., the International Phonetic Alphabet) is that all the Barker graphic symbols are readily identifiable as letters of the English alphabet. Hence, in spelling, the graphic sound representation of a word is spelled exactly like the standard alphabetical representation of that word. When an alphabetic symbol has more than one possible sound (e.g., c, s, th, vowels), the position and/or form of the letter symbol indicates the appropriate sound for the word (i.e., spelling choice) under consideration. For example, when c, s, and t are voiceless, they are located one-half space above the home line of type; if they symbolize voiced sounds, they are located one-half space below the home line of type. A vowel followed by a space is always accorded the long vowel sound, and any letter crossed by a slash mark is a silent letter. Outline and shaded letter symbols represent diphthongs and other special sound combinations. Each student is provided with a pronunciation key (on paper) illustrating each symbol as its sound occurs in a common word.

In the instructions for the pretest and posttest, each student is informed that he can touch his light pen to the word "help" (which appears in the same spot on the screen with each test question) if he wants to see how the choices are pronounced. The program permits him to return to the pronunciation (i.e., "help") section as many times as he wants on each question. Counters are programed to keep track of the number of times each student uses the "help" section for each of the five different error categories being tested.

Items covering the five error categories are presented in the same order on the pretest and the posttest. Thus, the pretest contains a total of 50 items arranged in 10 groups of the following error categories: the doubling of final consonants, ie-ei words, the formation of plurals, words ending in silent e, and words ending in y. The posttest contains a total of 100 items arranged in 20 groups of the same error categories.

Because the students for whom this course was planned are older adolescents, an attempt has been made to make the test sentences as unlike the usual, unimaginative, monotonous spelling-test sentences as possible, while at the same time making them clear and not so interesting as to be distracting.

Depending on each student's performance on the pretest, he is judged either to be in need of instruction in one or more of the five error categories, or not to be in need of such instruction. If, on the pretest, a student makes no more than two errors in each category (i.e., if he misspells no more than two out of ten words in a single category) he is judged to have performed satisfactorily and he does not receive instruction in that error category. Each category is judged separately, so a student could make as many as ten errors (i.e., two errors in each of the five cateogries) and yet not be routed into instruction. The justification for this criterion level is that two errors out of ten possibilities represents an accuracy level of 80%. Since the expectation of perfect English spelling may be an unrealistic one for human beings, we settled on 80% accuracy as indicative of knowledge and skill well beyond the level of chance, yet within the scope of attainment for students enrolled in post-high school study programs.

When a student makes more than two errors in a category, he is automatically routed to the instructional section dealing with the kind or kinds of errors that he made. After completing all instruction indicated as necessary (on the basis of his pretest score), a student is explicitly branched to the posttest, where the same criterion level holds. Hence, on the posttest, if a student spells 80% of the words in a category correctly, he is judged to have achieved a satisfactory level of spelling performance (i.e., he makes no more than four errors out of a possible twenty in each of the five cateogries).

Only as a means of gathering information about the tests, we have, at this level of development, given the posttest to students who achieved our no-instruction criterion on the pretest. Ordinarily such students would be dismissed after taking the pretest.

Any student whose pretest score indicates that he needs instruction in one or more of the five error categories, is systematically branched into a short, prologue segment called "Spelling Patterns." This segment has two basic purposes: 1) to alert the student to the presence and prevalence of patterns in English spelling; and 2) to present basic expository information about vowels and consonants. The first of these purposes is essentially an attempt to draw upon a linguistic approach to the study of spelling, in contrast to the probable, "There is no rhyme nor reason to English spelling" approach which most of our young adult students had previously encountered. The second purpose was merely to ascertain that the students were knowledgeable about two fundamental terms (consonants and vowels) which are used extensively in certain of the instructional segments.

The CRT's potential for animated presentation of material permits the author to emphasize particular patterns and to build on those patterns in accord with the concept(s) being dealt with at the moment. This animation capacity of the CRT has, as the authors anticipated, proved to be one of its most appreciated advantages--especially when the subject matter is approached rather reluctantly by students who have a general and prolonged history of failure in the subject. Both the content (i.e., the fact that there are patterns in English spelling) and the graphic treatment of the content (i.e., meaningful arrangement and animation) tend to rekindle hope in the students that this time they might really learn how to spell. The patterns prologue received favorable comments--sometimes accompanied by pleasant surprise.

The doubling instructional segment is concerned with teaching students how to determine whether or not the final consonant on a word should be doubled when a suffix is added to the word. To begin with, the student is asked to distinguish between vowels and consonants. If he fails to do so satisfactorily, he is given a brief review on consonants and vowels. The instructional segment uses significant animation extensively, illustrating doubled consonants, the settings in which they occur and do not occur, and the rule of the syllable number and accent, as well as the significant element in the suffix to be added to the root word. After the instructional program has shown the separation of words into their roots, suffixes, and doubled consonants (where necessary), the student is presented with a series of internal quizzes in which he must decide whether to join the roots and suffixes just as they appear on the screen, or whether or not to double the final consonant on the root word before adding the suffix.

When the student has passed this point, he is presented with a statement of the rule and then is quizzed on its application. After each unit of instruction, the student is quizzed until his performance score reaches criterion; then he is directed into a different and/or a more complex aspect of the topic. The tone of the evaluative feedback is designed tc be appropriate for the student's performance: gentle and supportive at first, more matter-of-fact as the number of trials to criterion increases. Drill-and-practice is extensively interspersed with internal quizzes in all instructional segments

Spelp - (IBM 1500 Computer System)

Spelp is a computer instructional program for the understanding of prefixes and suffixes. The course contains a description of 1) the relationship among prefixes, suffixes, and root words, 2) an exercise in typing the root when prefix and suffix are given, and 3) an extensive drill in choosing the correct word meanings when the meaning of the prefix is known.

Engineering Science

Engineering Science - (IBM 1410 Computer System)

The planning of this course in engineering science (Gilman, 1965) included comprehensive examination of the engineering technology and physics curricula of many vocational institutions. Most of the available texts in technical physics were reviewed.

Because there is a certain amount of subject matter common to physics and mathematics, these areas were programed first. Topics in scientific notation, the metric system, working with units, significant figures and kinematics were programed and tested by student subjects. Also, a chapter explaining the relationship between physics and engineering was programed and is available. Short segments in magnetism and atomic energy were written and tested.

The overall instructional strategy for CAI Engineering Science and Technical Mathematics begins with a common subject and branches into separate technically oriented mathematics and physics courses. However, the separate courses are correlated, so that instruction in physics topics are preceded by the prerequisite mathematics for that topic.

The physics curriculum includes beginning material of mechanics, heat, matter, electricity, magnetics, electronics, modern physics, light, and sound.

Technological adaptations of physics knowledge are stressed to a great degree. The structure of the science of physics is emphasized and provides a valid framework for learning fundamental concepts. A summary of the course segments in Engineering Science and their content are summarized below:

Introduction to Physics. An introduction to the science of physics. This segment describes the relationship of physics to engineering and chemistry, considers some elementary physics topics such as density, kinetic and potential energy, and the relationship between mass and energy. Estimated time: 1 hour.

The Metric System of Measurement. Teaches the student to use the metric system of measurement and to make conversions from one system to another. The student learns to make conversions through the proper multiplication and division techniques required for unit conversion. Estimated time: 1 hour.

Working with Units. This short course presents a different treatment to the use of dimensional analysis (also known as factor labeling) in working physics problems. The student is taught how to use the units given in a problem to find the units required in the problem's solution. Also, branching strategy is determined by student's error rate. Estimated time: 70 minutes. (Also programed are four experimental versions of Working with Units.)

Significant Figures. Determination of final accuracy in scientific experiments through the use of significant figures. Accuracy in measurement is considered and rules are given for finding the correct accuracy in the final result. Estimated time: 1 3/4 hours.

Use of Micrometer and Vernier Calipers. This segment teaches the use of the Vernier calipers and micrometer calipers as measuring instruments. The student first receives instruction on how to manipulate the instrument and to read the scales. He then makes measurements using the instruments. The student enters his readings at the terminal and they are compared with the measurements made by the course authors.

Calculus and Kinematics. A discovery approach to the relationship of velocity and acceleration to differential calculus. The student develops the ability to associate the first and second derivatives of differential calculus with the graphical representations of velocity and acceleration. Estimated time: 40 minutes.

Heat Part I. An introductory course on heat. The student is instructed in thermometry, kinetic energy of gases, and the expansion of solids, liquids, and gases. Estimated time: 2 hours.

Heat Part II. This is another segment of the introductory course in heat. In this segment the student is introduced to the concepts of specific heat, calorimetry, and the states of matter. Estimated time: 1 1/2 hours.

Electrification. Includes theory of electrostatics; Coulomb's Law and relationship between forces and electrical charges. Estimated time: 1 1/2 hours.

Magnetism. A very basic treatment of magnetism designed as introductory material to electromagnetic circuits and devices. Estimated time: 75 minutes.

Optics Part I. An introductory course in optics. In this segment, the student is presented instruction in illumination, reflection, and refraction. Estimated time: 2 hours.

Optics Part II. In this segment the student studies geometric optics as it applies to plane mirrors, curved mirrors, and lenses. Estimated time: 2 hours.

Atomic Energy. Utilizes the full facilities of computer-assisted instruction to present an elementary description of atomic energy. The student is taught the relationship between atomic weight and the numbers of protons and neutrons in the atom. Estimated time: 1 hour.

Mechanics. Adjunct auto-instructional program to provide supplementary instruction during testing in the area of mechanics. Estimated time: 45 minutes to 2 hours.

Kinematics. Adjunct auto-instructional program to provide supplementary instruction during testing in the area of kinematics. Estimated time: 45 minutes to 2 hours.

Meteorology. This metro segment includes the physical and meteorological aspects of heat and scales commonly used on thermometers, and the common type of thermometers.

Simulated Laboratory Physics Exercise. Sl physics is a simulated laboratory physics exercise designed to provide the student with the concept of the variables involved in a simple example of uniform, circular motion. The student is instructed to identify the variables in the situation, hypothesize the relationships between the variables, request data, and evaluate his hypotheses. The student may request information pertinent to the physical situation on terms relating to the situation.

Science, General. Content of these two segments is designed to update student's science knowledge and to provide student with more adequate science concepts. Both segments automatically connect to tc physics, a macro program of pre-programed options which an author can use to specify strategies for any question frame.

Measurement and Evaluation

Several courses are available on the IBM 1410 computer in the measurement area. A brief description follows:

Student Opinion Survey. A CAI segment, administered on line, is a measuring instrument to evaluate the student's attitude toward computer-assisted instruction. Twenty questions are presented via 2 x 2-inch slides; the system records the student's response and assigns a value of one through five to the response depending upon where it lies on the continuum. System types out score, which may range from 1 to 100, and the accumulated response latency. Estimated time: 20 minutes.

Computer Aptitude Test. Pretest for compat (computer aptitude test). A preliminary CAI ability measure designed for sequential presentation at the student terminal. Estimated time: 30 minutes.

Remote Associates Test. Computer administered Remote Associates Test of creativity. Thirty questions are presented via 2 x 2-inch slides. Those that are skipped are presented again and then a third time if skipped the second time. Individual and total response latencies are printed out for each question as student proceeds, plus the total score and the number of questions missed. Estimated time: 50 minutes.

Plan for the Development of A Pilot Computer-Assisted Occupational Guidance Program

The purpose of this section is fourfold: 1) to describe the initial computer-assisted occupational guidance (CAOG) program developed in the Department of Vocational Education at Penn State; 2) to present the results of two field trials, in which the program was utilized; 3) to describe the second generation version of the program developed in the CAI Laboratory; and 4) to present a planned third generation program and the rationale upon which it is based (Impellitteri, Kostenbauder, and Paolone, 1968).

Description of Original Version of CAOG

The efforts devoted to the design and development of the initial prototype of CAOG were a reaction to a growing concern. The objectives of the original project were, as stated in the Phase I report (Impellitteri, 1968): a) to develop a pilot occupational information retrieval and transmission system which would stimulate a selected segment of the ninth grade population to explore occupations on their own; b) to structure the occupational information transmission and the procedures by which the information is retrieved in such a way as to develop in the boys who are exposed to the system the acquisition of strategies for career exploration; and c) to develop a vocational guidance support system focusing upon occupational information which represents an integral part of the total guidance services in a school.

The focus of the initial program was upon the storage and transmission of occupational information by way of a computer-based terminal device as a vehicle by which youngsters would be both motivated to further exploration of occupations and stimulated to develop their own individualized strategies to undertake those explorations. A brief description of the hardware, software, and nature of the interactive process which was utilized in an attempt to fulfill the stated objectives is presented in the following discussion.

The student terminal provided the means by which a student interacted with the system. The terminal, connected to an IBM 1410 computer by telephone lines, was composed of an electric typewriter, a tape recorder, and a slide projector, all under computer control. The computer presented selected materials to the student, who was seated at the terminal, by either typing out a message through the typewriter, displaying a particular image on the slide projector, or by playing a previously recorded message on the tape recorder. The student transmitted meaningful messages to the computer by typing a short response on the typewriter. This short response required of the student was considered to be essential since longer typed messages would have required a level of typing skill not ordinarily achieved by most ninth grade boys.

Information related to a certain student's abilities, preferences, and educational plans were stored in the computer before the student began the interactive phase. The student was oriented to the purposes of the system before he began the first session. At that time, he was given a list of 40 occupations with corresponding codes representing his primary entry into the system. The computer's first request to the student was to ask him to select one of the 40 occupations on the list about which he would have liked to have known more. After the student responded by typing an occupational code number, the computer typed out a short paragraph very briefly describing the occupation. The student was then asked if he wished to find out more about the occupation. If the student responded positively, four operations were activated in the following order: 1) discrepancies which may have existed between the student's ability-preference profile and the requirements for the particular occupation were typed out; 2) a two-minute taped interview with a worker in the occupation was played; 3) an image was projected on the slide projector screen depicting the worker undertaking four typical tasks in the occupation and 4) a 150 to 200-word description of the occupation was typed out for the student to read, and to keep for later use.

The student was allowed to proceed through as many occupations as he wished during as many 40-minute sessions as he chose to spend. He may have, at any point in the process, indicated that he would have liked the computer to select for him those occupations from the list of 40 which he might have been interested in exploring further. The computer, by comparing the aptitude-preference profile for the student with the 40 occupational profiles sought those occupations for which no discrepancies existed, it listed those occupations for the student.

Results of the Field Trials

In order to assess the outcomes of the field trials a substantial amount of data was collected. These data included:

1) amount of time voluntarily spent by each student with the terminal (Roosevelt High School sample only);
2) number and type of occupational descriptions requested by each student;
3) reaction of each student to the equipment, the content and procedures utilized, as measured by a 44-item inventory;
4) students' expectations of the experience; their changes in awareness of self as related to work; the degree to which their horizons of occupational opportunities increased or decreased; the degree to which students developed an exploration strategy; and the degree to which students were stimulated to seek additional information regarding occupational opportunities--all collected by way of a 30-minute interview immediately following the terminal experience (Roosevelt High School sample only);
5) change in expressed tentative occupational choice between September and March for the group having the terminal experience as compared to a similar group of vocational-technical bound boys not having the experience and a group of non-vocational-technical bound boys (Roosevelt High School sample only);
6) selection of tenth grade course of study as compared to previous two years selections at the same school (Roosevelt High School sample only);
7) changes in occupational values as measured by a 35-item inventory, and
8) changes in the students' general knowledge about occupations as measured by a 149-item test (Keith High School sample only).

An extensive analysis of the data listed here appears in the Final Report of the Phase I project (Impellitteri, 1968). Because of the broader purposes of this paper, only summarized portions of the more significant analyses are presented.

Description of Planned Program

A revised, more highly structured heuristic approach has been designed. The following discussion is an attempt to describe the content, sequence and the nature of the student's participation during the interactive process.

The first phase of the computer terminal experience for a student requires him to select three occupations from a list of 144 occupations representing a reasonable sampling of opportunities in the world of work. The three occupations the student is required to select from the list represent three tentative occupational choices. The computer has access to 288 other occupations, some of which may be presented during the student's terminal experience. The student, however, must select from the list of 144. This requirement has merely been conceived as a convenient starting point. The numbers of selections, and stored occupations have been set rather arbitrarily.

The next step in the program is to check on whether any meaning can be translated from these three choices (elementary level of "occtalk" to "psychtalk"). This check has been built into the program as a five-item test with feedback on each of the three occupations. Each of the five multiple choice test items have been designed to measure a student's knowledge about one of the following aspects of each of the three selected occupations: 1) duties and typical tasks; 2) educational requirements; 3) training requirements; 4) working conditions; and 5) opportunities for advancement. The feedback for each item is essential in that it either crystallizes the perception of the youngster about an occupation, or it clarifies his perception. The nature of the feedback takes the form of either; "Good! Your answer is correct._____."; or "Incorrect._____." In either case "_____" represents a one or two sentence description of the particular aspect of the occupation in question.

The final stage in analyzing each of the three occupations is to give the youngster an opportunity to replace the occupation in question with another which might appear to be more appealing to him after finding out something about the originally listed occupation. Replacement then requires the student to go through the same process of questioning with the new occupation on the list. The student's score on each five-item test, his total score, his score on each of the five areas across the three occupations, and the number of replacements he chooses to use are stored in computer counters for use later in the program.

The procedure continues after the student has reached the stage when he is relatively satisfied with the three occupations finally listed. The computer then presents the following message via the CRT:

> "When a ninth grade boy states what he thinks are possible occupations which he might enter in the future, he may be indirectly indicating something about those kind of activities he likes to do. Let us examine if you have shown something about yourself in selecting the choices you listed."

The computer proceeds to compare an interest profile developed for each of the three occupations listed based on a dichotomous scale (Significant/ Non-significant) of each of the ten Kuder Interest Inventory dimensions. Only those coincidences of three occupations having the same significant dimension are noted for further consideration. If there are no coincidences of three occupations, the computer searches for two of three on any of the dimensions.

On the basis of its search the computer then presents the following message:

> "In selecting the three occupations which you have listed you have indicated that you may have a preference for working with numbers and a preference for working with machines and tools."

The student is then asked about each of the areas of interest which were underlined in the message, one at a time. He is asked, "Do you think you have a preference for working with numbers?" After the student answers "yes" or "no," the computer then verifies this answer on the basis of the student's coded (Significant/Non-significant) Kuder scores which have been stored. It then feeds back information on the accuracy of the student's perception. When each of the interest areas have been presented, the student is then asked, "Would you like to examine other occupations which might be in line with the preferences you have expressed?'

If the student answers "no" to that question he is asked to consult a list of the ten preference statements of the Kuder, and to indicate his major preferences. These then are verified in the same manner as previously described. All students should, whether they have answered "yes" or "no" to the question, reach the next step of the program. That step requires the student to consult another list which allows him to specify further those characteristics, if any, he wishes to impose on the following selection. Those possible characteristics include:

1) Any one, two, or three of the nine aptitudes of the GATB (U. S. Employment Service), listed by statements like, "Ability to deal accurately and quickly with numbers," etc. Each of these aptitudes, if selected, by the student is verified in accordance with the same procedures utilized in the verification of perceived interests.
2) Four areas of school achievement (mathematics, language, science, social studies). These also are verified in accordance with previously described procedures.
3) Educational level--college vs. non-college.
4) Amount of physical activity involved in the work--much vs. some vs. none.
5) Primarily indoor or outdoor work.
6) Salary level.

For each of the 432 occupations in storage each of the characteristics above are coded in some way. This feature allows the computer to access, based upon the student's stated restrictions, 429 occupations minus the number of occupational replacements made by the student. Each of the 429-R occupations which are identified by the computer are presented via the CRT to the student. If five or fewer occupations are identified in accordance with the student's restrictions, the computer will suggest that the student pick out the least important characteristic he chooses, and eliminate it. At the point where five or more occupations have been presented to the student (plus the three originally selected by the student) it is suggested that the student may wish to visit the library, counselor's office, etc., to uncover more information about these or other occupations.

The final phase of the program orients the student to focus upon the characteristics he selected. For instance, if he indicated no aptitude area as being important, he will be asked to select what he feels is the most important of the nine abilities and to note the differences between the original list of occupations and the new list. He is asked to make some comment about the difference from a list of five statements presented to him. This technique is also used for the achievement area as well as educational plans.

Through the kind of experiences provided for the student in this revised program, it is hypothesized that he will develop a unique framework of the world of work as well as an operational strategy in exploring his place in it. For ninth graders, whose entry into the exploratory stage is imminent, it seems that such an objective is essential, and should be an important determinant in the planning and development of the total ninth grade educational program.

CHAPTER V

SYSTEMS PROGRAMS

Geometric Dictionary

There are at least four advantages in using a geometric dictionary on the computer-controlled CRT display (Peloquin, 1968). First, the geometric dictionary uses less core storage than a graphic set, yet there is no limit to the number of line drawings which can be made. Because the components of a dictionary are small, they become more general and may be used in many different combinations. By analogy, a graphic set may be equated to a vocabulary of 64 words, while the geometric dictionary may be equated to an alphabet of 128 letters. The geometric dictionary may be equated and used within various courses thereby conserving core storage. Second, the necessity of keypunching each and every one of the line drawings dot by dot is eliminated. Third, the geometric dictionary allows the author to construct, on-line, the graphics for his course. This ability allows him to instantly see the line drawing as it is entered and make necessary changes or corrections. Fourth, words and line drawings can be combined without the one column gap necessary when using a graphic set.

There are, of course, some disadvantages as well. The geometric dictionary has been designed for producing moderate and large-sized line drawings. Except for some gross shading, such as "blackened" areas and hachures, the figures produced with this dictionary have been only line drawings. Some constraints are placed upon the drawing by the availability and the nature of the line segments. This restriction necessitates careful planning, but with the help of the IBM 1500 Instructional Display Planning Guide sheets it does not constitute a serious problem. Usually the addition of an extra character into the dictionary or a bit of programing ingenuity will overcome problems in producing still or dynamic line drawings.

General Description

The geometric dictionary consists of line segments entered as dictionary characters which may be manipulated as such. Throughout this description the characters appearing on the terminal keyboard and on the CRT under the system dictionary, whether letters, symbols, or numbers, will be referred to as "associated keyboard characters." The characters containing the line segments of the geometric dictionary will be referred to as geometric characters, and the line parts contained within each of the geometric characters will be referred to as line segments, whether straight line segments, arcs, or special characters. Since we are dealing with dictionary characters, once the geometric dictionary has been called by a dictionary change the geometric dictionary has all the operating characteristics and functions of the system dictionary. A particular line segment is called and displayed on the screen by entering the associated keyboard character in a display text (DT) or display text insert (DTI) instruction. For example:

```
DT  12,10///*laaaaa*b*b78 a a a a a 78*b*aaaaa*e
```

After a dictionary change (denoted by *l) is made, this instruction will display the "a" as a horizontal straight line and the numbers "78" as the left and right half of a small circle respectively. The backspace function (*b) has been used to superimpose lines.

Procedure

Sketching

The procedure involved in the construction of a line drawing requires three steps: sketching, coding, and entering. First, a sketch of the line drawing is made on an Instructional Display Planning Guide. The sketches should be rather simple and should be constructed of those line segments that the programer knows are available in the dictionary. On the three pages following this description of the first step are reference pages indicating the orientations of the line segments that are presently available to the programer. It is recommended that these reference pages be reproduced in a transparent form in order that the programer may overlay the available line segments on his sketch for comparison. The reader is reminded that each geometric character may be used independently. Thus if the third (and middle) character of a 30° line is needed, it may be used independently of the other four geometric characters which make up the completed line. If the programer cannot match his sketch with an available line, he should select the closest approximation and revise his sketch accordingly. A limited number of special characters may be inserted into the geometric dictionary if the programer finds that their omission seriously handicaps him. Additional flexibility can be gained by the use of the keyboard functions such as space, backspace, index, reverse index, and dictionary change. Superimposition, offsetting by a half-line, the display of text and geometric figures in juxtaposition or superimposition, the display of only half of a geometric character, and shading are some facilities gained by the use of standard keyboard functions. With a little practice, the programer's familiarity with the lines available in the dictionary should grow to a point where he will be able to produce sketches which require no lines that are not already in the dictionary. In anticipation of the second step, the programer may wish to make mental or written notes on the line segments he intends to use in constructing the line drawing.

Coding

The second step in constructing a figure with the geometric dictionary may take place once the sketch in the Instructional Display Planning Guide contains no lines which are not in the geometric dictionary.

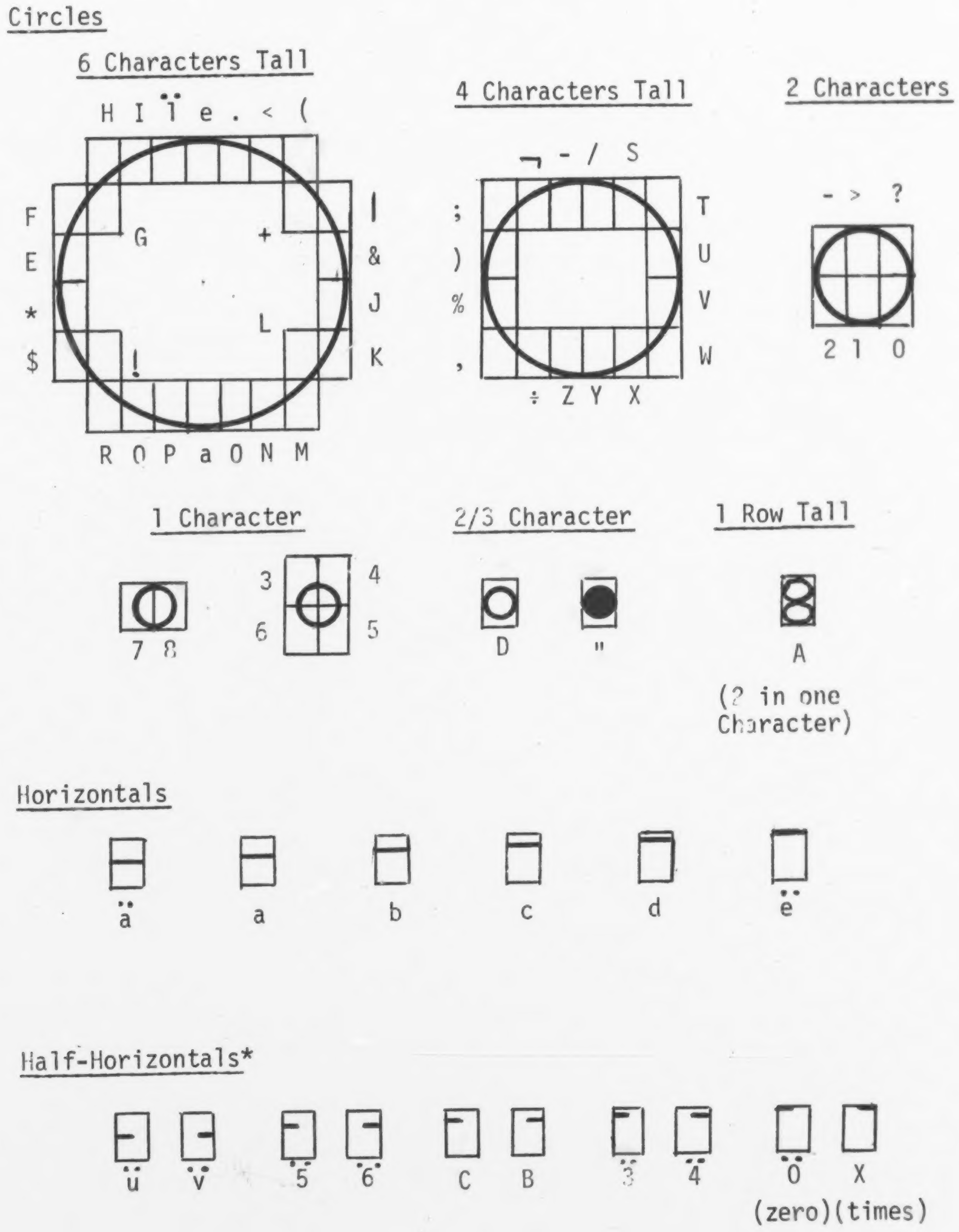
The two reference pages following, Figure 3, are used in the "short form" of encoding. The reader should note that the associated keyboard characters are written beside, above, or below the geometric characters to which they refer. One simply chooses the line segment and geometric character he wishes, then encodes the associated keyboard character.

The use of the long form is not described here since simple line drawings can easily be constructed with the use of the short form. More complex figures requiring knowledge of every lighted dot within the character would necessitate the use of the long form.

Entering

The third step involves the on-line entering of the coded line drawing. This step may, of course, be altered by entering the coding on cards. The

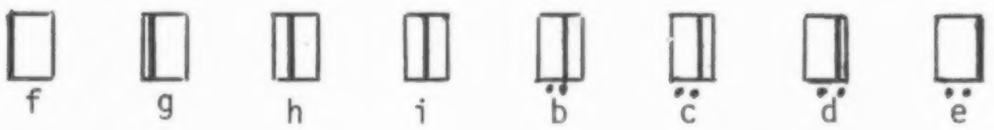
PSU GEOMETRIC DICTIONARY
SHORT-FORM DOCUMENTATION


Circles
6 Characters Tall
H I ï e . < (
F
E
*
$
G
+
L
!
|
&
J
K
R O P a O N M
4 Characters Tall
¬ - / S
;
)
%
,
T
U
V
W
÷ Z Y X
2 Characters
- > ?
2 1 0
1 Character
7 8
3
4
6
5
2/3 Character
D
"
1 Row Tall
A
(2 in one Character)
Horizontals
ä
a
b
c
d
ë
Half-Horizontals*
ü
v̈
5̈
6̈
C
B
3̈
4̈
0̈
X
(zero)(times)

*There are no half-horizontal lines in the position equivalent to the horizontal a.

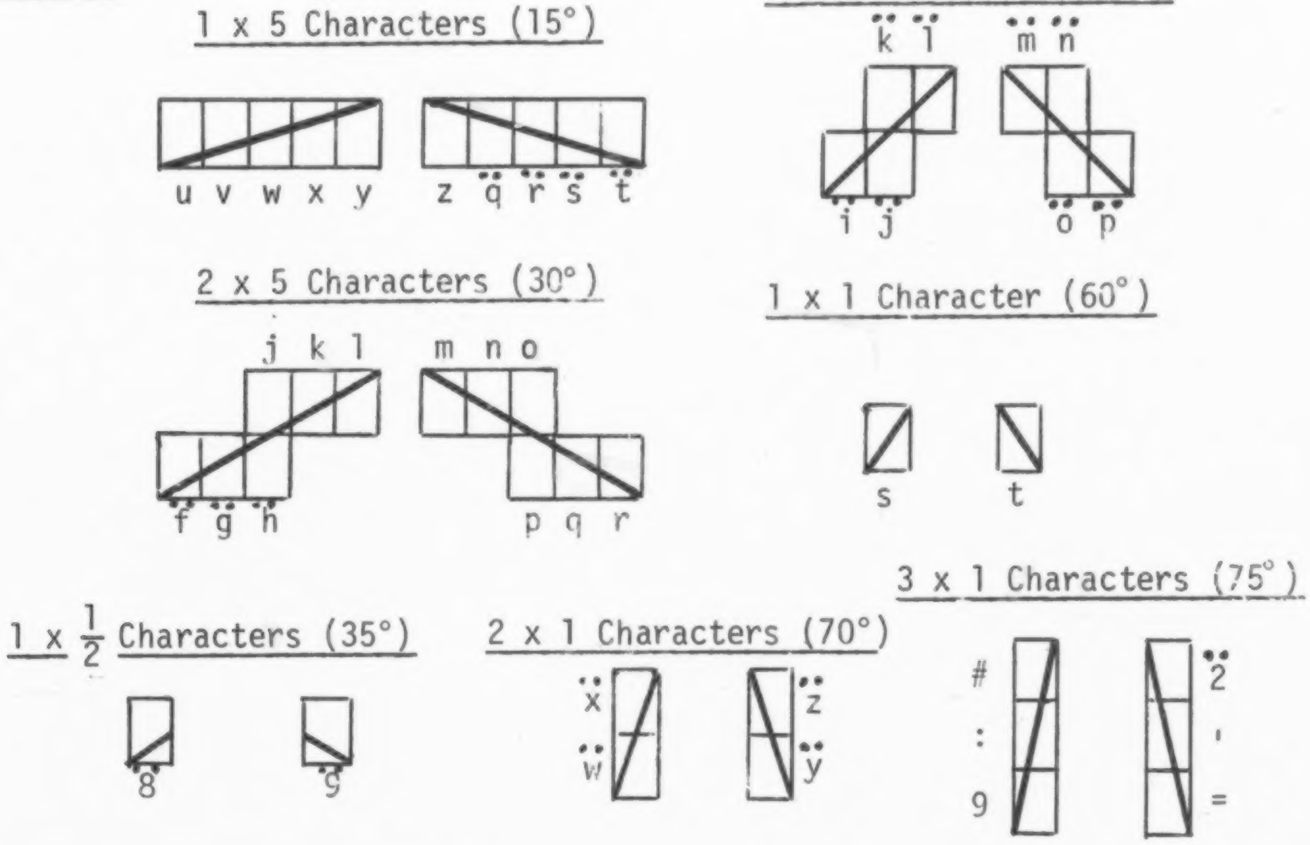
Fig. 3. Short form documentation.

Verticals - Short Form Documentation - (Cont.)



Diagonals

2 x 3 Characters (45°)


1 x 5 Characters (15°)

2 x 5 Characters (30°)

1 x 1 Character (60°)

3 x 1 Characters (75°)

1 x $\frac{1}{2}$ Characters (35°)

2 x 1 Characters (70°)

k l
m n
u v w x y
z q r s t
i j
o p
j k l
m n o
f g h
p q r
s
t
#
:
9
2
'
=
8
9
x
w
z
y

Shading

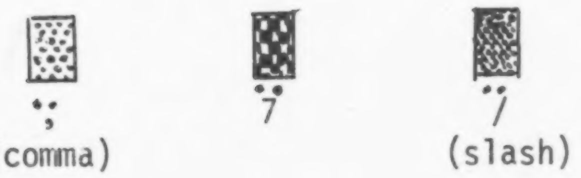

;
(comma)
7
/
(slash)

Fig. 3 continued. Short form documentation.

advantage of entering on-line is that the programer may see the portions of the drawing as he enters it, thus allowing him to correct or change the coding and the drawing.

A Processor for Multiple Numeric Entries - (IBM 1410 Computer System)

For the sequential testing program it was desired that a student be allowed to respond to multiple choice questions in the embedded tests by stating his subjective probability or degree of belief for each of the choices presented. It was further desired that the mode of responding not be unduly time consuming or unnecessarily restricted in the range of format variations accepted. Due to the time factor involved following each student response on the 1410 system, it was not desirable to have the student enter his subjective probability for each choice separately. If the student was to be allowed to enter his subjective probabilities for all choices in a single response, there were two possible ways of processing the response in which the information concerning the subjective probability for each choice would be preserved. A series or "stack" of possible answers could have been provided in the program against which to compare the student's response. However, because of the number of combinations of subjective probabilities possible and the permutations possible for each combination, it was impractical to employ this procedure.

The alternative procedure (Bahn and Brown, 1968) entailed evaluation of each subjective probability in the student's response when the individual probabilities were themselves components in a string of probabilities which made up a single response. No such capability exists in 1410 Coursewriter. The subroutine described here provided this capability and was employed in the previously referenced instructional program.

The algorithm for the multiple entry subroutine is as follows:

1. The student's response is entered in the form:

```
xx, xx
xx, xx, xx, xx

or

xx, xx, xx, xx, xx
```

where xx is any two-digit number within the range 00 to 99 or the three-digit number 100.

2. An edit function deletes extraneous spaces, letters, and special characters.

3. A series of edit functions rounds the numbers in the student's response to the nearest ten and converts the number 100 to 99.

4. The response is now in the form:

yy, yy
yy, yy, yy, yy
or
yy, yy, yy, yy, yy

where yy is a member of the set of numbers (00, 10, 20, 30, 40, 50, 60, 70, 80, 90, 99).

5. Response processing now enters a series of twenty-two (22) to fifty-five (55) initial character function (ic fn) calls depending upon the number of entries (2, 4, or 5) and the values of the entries. The initial character function allows one to compare n initial characters of a response and to include "don't care" characters (in this case $) which will match any single character in the string of characters which is to be matched, i.e., "wild" cards in poker.

6. The first set of initial character functions compares the first three (3) characters of the student's response with answers of the form:

yy

7. The second set compares the first seven (7) characters of the response with answers of the form:

$$, yy

8. If only two (2) entries were required, processing passes to step 13.

9. The third set of functions compares the first eleven (11) characters with answers of the form:

$$, $$, yy

10. The fourth set compares the first fifteen (15) characters with answers of the form:

$$, $$, $$, yy

11. If only four (4) entries were required, processing passes to step 13.

12. The fifth set of functions compares the first nineteen (19) characters with answers of the form:

$$, $$, $$, $$, yy

13. Each time an entry was matched, its value (yy) was placed in a counter corresponding to its original position in the total response. These counters are now added together to see if their total is one hundred (90 to 110 to allow for rounding error).

14. The entry with the highest value is loaded into counter six (c6) and a switch is set to indicate the original position of this value.

15. Control is returned to the main program.

With the the advent of the IBM 1500 instructional system and the extract integer function (er fn) this same procedure can be implemented with fewer statements and greater accuracy. A macro has been written to accomplish this task.

CHAPTER VI

RESEARCH STUDIES

Relationship Among Attitude, Achievement, and Aptitude Measures and Performance

Purpose

The main objective of the investigation (Wodtke, 1965) was to examine relationships among academic aptitude, past achievement, and performance in CAI to determine whether the results of previous investigations can be generalized.

Methods and Procedures

Forty-five college students completed a section of a course in modern mathematics which was presented by means of computer-teleprocessing. The student terminal consisted of an IBM 1050 communications system consisting primarily of an electric typewriter as an input-output device. The frames of the program were typed out to the students at the typewriter, and the students entered their responses by typing them at the terminal. Responses were evaluated by the computer which kept track of the students' performance by accumulating their errors and response latencies in counters. These error and response latency data were later retrieved by means of a Student Records program developed by IBM computer scientists.

Each student was scheduled for a three-hour instructional session. Upon arriving at the CAI laboratory, each student was pre-examined on his knowledge of the content of the modern mathematics program. The student was then given a warm-up period to familiarize himself with the operation of the student terminal. Following the warm-up period, each student completed a section of the modern mathematics course on number systems with bases other than ten. Most students completed the course in about 2 to 2 1/2 hours. The course contained instruction in base eight, base five, and base two number systems, and transformations from one base to another. The modern mathematics course has been found to be fairly difficult for the average college student, and only a few students exhibit prior knowledge of the concepts as indicated by their performance on the pretest. Following completion of the course, students were given a criterion measure of their achievement in the course, and responded to a number of attitude scales modeled after the Semantic Differential scales (Osgood, Suci and Tannenbaum, 1957). The criterion achievement test was found to have a test-retest reliability (one-week interval) of .93 in an earlier study by Wodtke, Mitzel, and Brown (1965). The attitude scales were designed to measure the students' reactions.

Summary

The results of the present investigation may be summarized as follows:

1) The present results do not agree with the results of several previous investigations which found nonsignificant relationships between achievement in programed instruction and measures of general intelligence. Significant correlations were obtained between Scholastic Aptitude Test scores and a criterion measure of achievement in modern mathematics presented by computer-assisted instruction. Although it may be reasonable to expect individualized programed instruction to reduce individual differences in student achievement in some content areas, student performance in other content areas may depend on requisite skills and abilities which have deep roots in many years of previous training.

2) Cumulative college grade point average was found to correlate significantly with modern mathematics achievement level prior to CAI instruction, but did not correlate significantly with post-instruction achievement level. This result suggests that grade point average reflects the amount of prior achievement, but is not a good predictor of how much a student will learn in short periods of instruction via CAI.

3) The best predictors of student errors made during CAI were SAT-M, SAT-V, CGPA, and response latency in that order. The results suggest that the latency of a student's response might be used as a signal to the computer to present remedial instruction and thereby prevent the occurrence of an incorrect response.

4) A measure of the students' attitudes towards CAI indicated that college students generally reacted favorably to the experience. However, men tended to react more favorably than women, and high-aptitude students tended to react more favorably than low-aptitude students.

5) Nonsignificant relationships were obtained between attitude towards CAI and performance in the course when the effects of aptitude were partialed out.

Scrambled vs Ordered Course Sequencing

Purpose

The primary purpose of this investigation (Wodtke, 1965) was to determine the interaction between student aptitude and scrambled vs ordered sequencing of instruction. This study employed a fairly lengthy instructional program of considerable difficulty for the average college student. The material used involved the learning of principles, mathematical problem solving, and contained a large number of sequential dependencies among the concepts taught. The specific objectives and predictions of the experiment were as follows:

1) To determine under what conditions careful sequencing of instructional programs "make a difference" in student learning within the context of computer-assisted instruction. Following appropriate hypothesis tests, it was predicted that scrambled item sequencing would have a detrimental effect on student learning in a relatively lengthy, difficult program containing many sequential dependencies among concepts, e.g., when the mastery of some concepts and principles are prerequisite to the mastery of other concepts and principles.

2) To determine whether scrambled as compared to ordered item sequences have a differential effect on students of high- as compared to low-verbal aptitude. An aptitude by sequencing interaction effect was predicted. Scrambled item sequences were expected to have a more detrimental effect on the learning of low verbal ability students than on the learning of high verbal ability students. It was thought that students of low-verbal ability would not have the conceptual skills required to reorganize the scrambled material.

Methods and Procedures

The course used was a section of a modern mathematics course which had been developed for CAI by the staff of the Computer Assisted Instruction Laboratory at Penn State. The material selected contains instruction on the use of number systems with bases other than ten. This learning task offers the advantage of being relatively difficult for college students to learn, and the material is unfamiliar to most students. The ordered version of the program presents subsets of items in the following sequence: review of the base ten system; the concept of place value; the application of the concept of place value in base eight, base two, and base twelve number systems; transformations from one base to another; addition and subtraction in numbers systems with bases other than ten; and multiplication and division in number systems with bases other than ten. Previous experience with these course materials indicated that most undergraduate college students could complete instruction in approximately two and one-half to three hours with a mean error rate of about fifteen percent.

Fifty-one undergraduate students in an educational psychology course at Penn State served as the Ss in the investigation. Ss with absolutely no previous typing experience were not included in the study. Two Ss were eliminated because a modern mathematics pretest indicated they had previous knowledge of number systems with bases other than ten. One other S was eliminated because his scholastic aptitude test scores (SAT) were not available. These eliminations brought the total number of Ss to 48.

Subjects were then subdivided into high- and low-aptitude groups on the basis of their scores on the verbal Scholastic Aptitude Test (SAT). The mean of the high group was 612 and the mean of the low group was 534 (SAT employs standard scores based on a mean of 500 and a standard deviation of 100). The original plan of the investigation was to assign Ss within each of the high and low aptitude groups at random to the scrambled or ordered instructional treatment conditions. Although approximately half of the Ss were assigned to treatments at random, the random assignment of a large number of Ss had to be altered due to a number of programing "bugs" which developed at the last minute in the scrambled sequence program. For this reason, a larger number of Ss who were scheduled for the early experimental sessions were run in the ordered sequence condition, and a larger number of Ss scheduled for the later experimental sessions were run in the scrambled sequence condition. The investigator had carefully examined the two groups of subjects and in spite of the nonrandom assignment of some of the Ss, can find no selective factors which could account for the results obtained in the study.

The dependent variables of the study were criterion test performance, errors made in the program, total time taken to complete the program, mean response latency per frame, an efficiency score obtained by taking the ratio of criterion test performance to instructional time, and measures of the students' attitudes towards CAI. The data were analyzed by means of a two by two factorial analysis of variance design with unequal numbers of cases per subcell. One experimental factor consisted of high versus low aptitude; the other of scrambled versus ordered program sequence.

Results

A preliminary analysis indicated that although the high- and low-aptitude groups differed significantly on the verbal SAT measure, the scrambled and ordered sequence groups did not differ significantly in verbal ability as measured by the SAT. In addition, an analysis of quantitative SAT scores produced nonsignificant differences among the four treatment groups employed in the study.

The distributions and the variances within groups of the dependent variables were examined to determine whether the assumptions underlying the analysis of variance had been met. None of the distributions appeared to deviate substantially from normality. Hartley's Maximum F-ratios were computed to test the assumption of homogeneity of variance. All of the F-ratios were nonsignificant except one. The F-ratio for the efficiency score was significant at less than the .01 level indicating the presence of heterogeneity of variance for this variable. In view of the results obtained by other researchers who found that heterogeneity of variance did not seriously bias either the t-test or F-ratio, the heterogeneity of variance for the efficiency score could not have seriously biased the results obtained in the present study.

In general, the results of the analysis of the main dependent variables of the study confirmed the initial expectations. The results indicated that students in the scrambled sequence group made significantly more errors during instruction than the students in the ordered sequence group ($P < .001$). Since the students in the scrambled sequence group were more likely to encounter remedial segments of the program (due to their greater tendency to make errors), than the students in the ordered group, the scrambled sequence group actually responded to more questions than the ordered sequence group. The differences obtained in the total frequency of errors might have resulted from the fact that the students in the scrambled group simply responded to more questions and thus had more opportunity to make errors than the ordered group. To control for this possibility, an analysis was also computed based on percent error scores. This analysis indicated that students in the scrambled sequence group made a significantly greater percentage of errors than the ordered sequence group. In spite of the highly significant sequencing main effect for frequency and percentage of errors, the sequencing main effect for the criterion test score was nonsignificant. Considered together, these results indicated that although the scrambled sequence students made significantly more errors during instruction than the ordered sequence Ss, they apparently improved their performance during instruction and, by the end of the course, they performed approximately at the same level as the ordered group on the criterion measure.

The data indicated that the predicted aptitude by sequencing interactions were obtained, The interactions for frequency of errors and the criterion measure were both very close to significance at the .05 level. However, the interactions which were obtained for several criterion variables did not result from a decrement in the performance of the low-aptitude group in the scrambled program as precicted, but from a decrement in the performance of the high aptitude Ss in the scrambled program. The results of the present study support the conclusion that scrambling an instructional program has little or no effect on the performance of low-aptitude students, but produces a rather marked decrement in the performance of high-aptitude students.

Rote Rule-learning on Transfer of Training

Major Objectives

1) By means of an experimental paradigm which simulated a common classroom teaching sequence, the study attempted to demonstrate the detrimental effects of adding rote rules-of-thumb to instruction designed to facilitate basic understanding and transfer of training.

2) The study also compared the effects on transfer of two rule practice sequences, one in which the rule was given after instruction but before a practice segment, and another in which the rule was given following both instruction and practice (Logan and Wodtke, 1966). (See Table 1 for the sequence of experimental events.)

Table 1

Experimental Sequences

Condition 1 (No-rules)	Condition II (Rules-early)	Condition III (Rules-late)
Pretest	Pretest	Pretest
↓	↓	↓
Basic Instruction: Significant Figures in Multiplication	Basic Instruction: Significant Figures in Multiplication	Basic Instruction: Significant Figures in Multiplication
↓	↓	↓
Practice Problems	Rule Given for Multiplication	Practice Problems
↓	↓	↓
Transfer Posttest: Addition and Trigonometry	Practice Problems	Rule Given for Multiplication
	↓	↓
	Transfer Posttest: Addition and Trigonometry	Transfer Posttest:

This comparison was designed to test the hypothesis that the addition of a rote rule-of-thumb to an instructional program which strives for understanding will, if it comes before the student is given a chance to use his basic understanding in practice problems, produce a decrement in performance on transfer tasks.

Another phase of the investigation examined the hypothesis that a condition in which a rule was given before practice would have a more detrimental effect on transfer than a condition in which the rule was given after practice. This hypothesis was based on the supposition that students would, if given the rule before the practice problems, practice using the rule, and would not exercise the problem-solving strategies developed in the basic instruction. On the other hand, students who did not have the rule available until after the practice session would be forced to solve the practice problems using the understanding of significant figures which was developed by the basic program. This hypothesis was not confirmed.

Conclusions

1) The presence of a rote rule-of-thumb in an instructional sequence designed to facilitate transfer to problems which were not specifically taught in the program, and to which the rule did not apply, produced a marked decrement in performance on the transfer tasks. The decrement on the transfer tasks was obtained by comparing an instructional program containing a rote rule-of-thumb with an identical program containing no such rules. The transfer decrement occurred in spite of the fact that the students were given a didactic warning indicating that the rule would not apply on the transfer problems. The results of the study indicate that didactic verbal warnings to students have little effect on their behavior in an actual transfer situation. The authors believe that the results of the present study are fairly typical of actual classroom teaching practice, and that much more care should be taken in preparing instruction which involves the use of rules-of-thumb in problem solving.

2) The present results indicate that it makes little difference whether the rule-of-thumb precedes practice or follows practice. In either case the presence of the rule inhibits performance on transfer tasks when compared to a group taught without the use of rules. For example, if one examines the

percentage of naive students in each experimental group which reached "mastery" on the addition transfer tasks, mastery being defined as perfect performance, one finds that only 20% of the rule-late group, 20% of the rule-early group, but 75% of the no-rules group reached mastery!

3) A supplementary examination of the responses made by the students in the transfer tasks indicated that the poor performance of the rule-groups resulted to a considerable extent from their misuse or overgeneralization of the rule. The misuse of the rule occurred even though students had been warned several times concerning the inapplicability of the rule to the transfer situation.

The writers do not take the present results to indicate that computational rules or algorithms should not be included in quantitative instruction, but only that teaching students to use such rules appropriately requires special instructional procedures which are frequently omitted in actual practice. The apparent tendency of students to overlearn a simple rule-of-thumb at the expense of their basic understanding of the processes involved would seem to indicate that much more care should be taken in the preparation of instructional materials designed to produce basic understanding and transfer of training. The results of the present study are probably most easily interpreted as a case of the students' failure to discriminate problems in which the rule applies from problems in which the rule does not apply. Perhaps the optimal instructional program would provide the basic understanding, useful problem solving rules, and the discrimination training needed to help the student avoid instances of rule misuse. Most instructional situations do not provide the discrimination training necessary to reduce the frequency of rule misuse. It is quite evident in the present results that this objective is not achieved by simple didactic verbal statements. As a general recommendation for teachers in quantitative subjects, if simple rules-of-thumb are to be taught, much discrimination training in the use of the rules will probably be necessary in order to avoid the students' tendencies to blindly apply the rules without regard to the appropriateness of the situation.

Although one might presumably argue that the present results indicate that rules-of-thumb should be avoided in quantitative instruction altogether, there are obviously many problem solving situations in which such rules have great utility. Ideally, a student should be able to capitalize on the increased efficiency provided by the rules in problem solving, but he should also be able to select the appropriate rule for a particular problem, and be able to rely upon his basic understanding of the processes involved when he recognizes that no existing rule applies.

Educational Variables

Purpose

The primary purpose of the present study (Gilman, 1966) was to compare an instructional program prepared by means of IBM's Coursewriter language for CAI presentation with a more conventional programed text. The feedback, prompting, and correction procedures available in the Coursewriter language were expected to produce increased student motivation, attention, achievement, and retention over time. The branching and decision-making capability of CAI was not examined in the present study.

Method

Subjects. The subjects were 66 ninth and tenth-grade students in the college preparatory curriculum at State College Junior High School. All were naive with respect to educational experimentation procedures and none had received instruction in physics. All Ss who began the experiment completed the experiment.

Design. Subjects were randomly divided into three groups. The randomization was accomplished by the use of a well-shuffled stack of student data cards. Ss were pretested with the ten-question pretest. No S answered more than 3 questions correctly and most answered all responses incorrectly.

Two of the groups received instruction by CAI programs. The first of these (CPF) received contingent feedback and prompting and students were required to answer the item correctly before proceeding. The second group (KCR) received instruction by means of a CAI program providing a statement of the correct response. The third group (text) received instruction through a programed text containing material and feedback identical to that of the KCR program. In all three groups, the instruction was completed in a single lesson.

All instruction was "stand alone" instruction in that no other instruction was provided other than the programed course. There were no difficulties with any of the equipment used during the experiment and the CAI groups experienced no down time or delays.

Conclusions

The major conclusions of the study may be summarized as follows:

1) No differences in learning and retention were obtained for a CAI program which incorporated response-contingent feedback, prompting, and overt correction procedures on the part of the student when compared to a CAI program which simply typed the correct response following a student response and proceeded to the next frame.

2) No differences in learning and retention were obtained for a condition in which an instructional program was administered by a teletypewriter communication device as compared to a condition in which the material was presented by means of a programed text.

3) The conditions in which instruction was presented by a CAI communication device took significantly more instructional time than the programed text condition.

The results of the present study appear to be consistent with the results of Swets (1962), Swets, Harris, McElroy, and Rudlow, (1964), and Stolurow and Davis (1960). Shurdak (1965), however, employed an instructional program which contained branching to adapt to the individual learner, diagnostic and drill questions, and computer-controlled and optional review. Shurdak's more adaptive program probably accounts for the superiority of his computer-based instruction group over programed and conventional text groups. The present study did not examine the branching question, but only compared different strategies for correcting student errors and providing feedback to the learner. The present findings bear on the question of the nature of feedback and correction procedures. These results tentatively suggest that less elaborate and straightforward feedback and correction procedures may be as effective as the more elaborate prompting, response-contingent feedback, and overt correction procedures.

Typewriter Interface

Nature and Purpose of the Study

For individuals not familiar with CAI terminology, the term interface (Wodtke and Gilman, 1966) refers to the input and output devices through which the subject matter is presented to the learner and through which the learner makes his response. The interface might include auditory communication devices, visual communication devices varying in sophistication from simple slide projectors to CRT displays, two-way typewriters of the type currently (circa, 1966) in use at Penn State, etc.

In discussions of the interface between student and subject matter in CAI, the typewriter usually draws a substantial amount of time. Some of the disadvantages which have been attributed to the typewriter interface are "penalizes the nontypist," "inappropriate for use with young children," "too slow in transmitting information to the student," etc. Some of the advantages ascribed to the typewriter interface have been "provides for constructed response," "permits remote teleprocessing," "provides hard-copy for the student," and so on. Some of our preliminary research raises some questions concerning the efficiency of the typewriter interface.

Several studies are presently being conducted on various problems related to individualized instruction. Two of the studies provide preliminary data on the efficiency of the typewriter as a communication device for high school and college level instruction. Table 2 presents part of the data of one study which compared equivalent instructional materials presented "on-line"[1] and "off-line" in the form of a programed text. This comparison is shown in rows A and B. Row C contains a condition we call a "linear coursewriter" program administered "on-line." This program differs from A and B in that each frame contains several prompts and cues designed to elicit a correct response from a student who initially makes an error. Condition D, a branching coursewriter

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[1] "On-line" in the present context means that all instruction was taken via CAI at the typewriter interface. "Off-line" means that the course was taken in the form of a programed text.

Table 2

Comparison of Mean Posttest, Retention Test, and Instructional Time for On-line and Off-line Instruction in Technical Physics (High School Student Sample)

	Pretest	Posttest	6-week Retention	Mean Instructional Time (minutes)
(A) Linear Programed text (off-line) (n = 22)	1.06	20.6	17.0	42
(B) Linear Programed text (on-line) (n = 22)	1.09	20.0	15.3	52
(C) Linear Coursewriter Program (on-line) (n = 22)	0.91	21.9	17.9	68
(D) Branching Coursewriter Program (on-line)	-	-	-	-
	n. s.	n. s.	n. s.	P <.001

program, was included in Table 2 to indicate the direction of future research. Through condition D we eventually hope to produce a program which adjusts instruction to relevant individual differences among learners to produce maximum achievement in a minimum amount of instructional time. The subjects in the study were high school students. The instructional program was relatively "nonverbal," consisting primarily of short questions and verbal communications.

Table 2 shows that although the posttest and retention scores were nonsignificantly different for the three groups, that the variations in instructional time were highly significant. The time lost by administering the same material via the typewriter interface was 10 minutes. (If two extreme subjects are eliminated from the "off-line" group the mean time drops to 35 minutes.) Comparing conditions B and C indicates that we lose another 17 minutes by adding prompts and by requiring the student to produce the correct response by typing it into the machine.

Similar data from another study using a small sample of college students and a program with longer typed questions and messages obtained a mean time "off-line" of 51 minutes (n = 8) and a mean time "on-line" of 80 minutes (n = 7). Several of the students in the "on-line" group took a short five-item pretest and five-item posttest which is included in their time, however; an adjustment for this additional activity still leaves a rather substantial time difference.

These time differences can be reduced to some extent by programing to eliminate a number of typewriter carriage returns which are currently built into our programs (each taking approximately 1.3 seconds). The time differences may also be reduced after students have had more experience working with the typewriter terminal and are able to operate it more rapidly. However, some portion of the time loss is undoubtedly due to the large difference between the typeout rate of the typewriter (approximately 120 words per minute) and the reading speed of the typical high school or college student. The average highly verbal student appears capable of assimilating information at a rate considerably faster than can be communicated to him through the typewriter interface. Obviously the instructional time lost will be greater for subject matter which is highly verbal in nature, and for highly verbal students. It is impossible to estimate the exact extent of the time loss for different subject matters at the present time. Admittedly, our data require replication with larger samples of students and different subject matters. However, in an area of research where instructional manipulations generally produce only small gains in student achievement, a time loss of the order of 25 percent represents a substantial amount. Students could be given 25 percent additional practice, instruction on new material, practice on transfer problems, etc. In addition to the gains in student learning which might result from a more efficient use of instructional time, there are also economic considerations in the cost of computer time, tie-lines, and other "hidden" costs involved in the preparation of the courses. All other things being equal, by employing an interface which would increase the amount learned per unit of time by say 25 percent, four students could be taught for every three taught by means of a typewriter.

It is also important to realize that from the college student's point of view, learning at a typewriter terminal is not self-paced instruction since he must slow down his normal rate of work. Pacing instruction below a student's optimal rate could produce boredom, negativism, and avoidance of CAI as an aid to learning. This is not an uncommon finding when the pace of classroom instruction by the lecture method is too slow for the brighter students.

What are the possibilities for speeding up instruction using a typewriter interface? We have considered the possibility of putting all lengthy, typed communications, and possibly all stimulus materials on slides for more rapid presentation to students. Two factors weigh against this proposal: a) the slide production and duplication problem becomes immense for any full length course used with a number of students simultaneously; b) the presentation of questions, problems, and other messages via the slide projector leave the student with no hard-copy as a record of his work. It would be much simpler to put all course materials in a display book and use the typewriter solely to direct the student to a particular question, problem, or display, and as a response input device. Following this strategy, the CAI system would not be used to display instructional material, but to evaluate student responses and to refer the student to appropriate display materials according to his progress in the course.

Another question which is frequently raised concerning the typewriter interface is the extent to which typing ability affects student performance. In the first study described above, students were identified as typists or nontypists on the basis of interview data. A comparison of the posttest achievement and retention scores of typists and nontypists showed no statistically significant differences. This finding is not surprising since the responses required in most of our programs are relatively short one-word or at most two-word responses. However, as might be expected, typing ability does appear to relate to the time variable particularly when the program requires much interaction between the student and the subject matter through the typewriter interface. Table 3 shows the mean times for typists and nontypists in programs B and C. Program B was the linear program which required only one response per frame; program C was the course which was programed to anticipate student errors, and to elicit a correct response by means of successive prompts. The time difference for typists and nontypists was 2 minutes on the average for program B, and 12 minutes on the average for program C.

Table 3

Typing Ability and Instructional Time (in minutes) at the Typewriter Interface

	Program B	Program C
Typist	n = 14 Mean Time = 51	n = 10 Mean Time = 64
Nontypist	n = 8 Mean Time = 53	n = 12 Mean Time = 76

Tentative Conclusions

1) On the basis of preliminary evidence the two-way typewriter does not appear to be the most efficient interface for transmission of highly verbal information to highly verbal learners. The typewriter interface transmits information at a rate considerably slower than the reading rate of typical high school or college students.

2) The typewriter interface would seem to be more appropriate for relatively nonverbal content areas and for students who normally work at a fairly slow pace.

3) The typewriter in CAI might be used more efficiently as a response entry device rather than as a device for communicating the subject matter.

4) The typewriter interface has the advantage of remote teleprocessing and makes available a printout of the instruction for the student.

5) Perhaps the optimal interface for highly verbal material, and highly verbal learners will be a rapid visual display device such as the CRT, with remote teleprocessing capability, and the ability to store, and later print out at the request of the student, a record of his exercises and actual responses.

Gradient- and Full-Response Feedback in Computer-Assisted Instruction

Purpose

It is appropriate to scrutinize the particular characteristics of a given system to determine whether or not there can be or is improvement in learning. Many of these characteristics or variables cannot be judged in terms of previous experimentation in the field of educational psychology because they exist only in CAI. Further, studies conducted in laboratory situations cannot be readily transferred to an educational environment. This study (Hall, Adams, and Tardibuono, 1967) attempted to remove one learning experiment from the artificial world of animal laboratories and nonsense syllables and to place it in an educational context.

Method

Programs were written for investigating the effectiveness of these two kinds of feedback - gradient- and full-response feedback. A paired-associate learning task was employed using fifty pairs which the student learned. The fifty state names of the United States were presented as stimulus items, and the student learned to respond with the names of the capitals. The items were presented individually, in random order, to the student at the typewriter terminal. If the student responded correctly (acquired) on his first attempt to that stimulus, it would be dropped from the program. The program recycled until each student had responded correctly on his first attempt to each of the items during one cycle. The number acquired on the first cycle through the program was used as a pretest score. After the student acquired each of the fifty pairs, the entire list was presented as a posttest. A retention test was administered to each student two weeks after the initial treatment. The program for each of the experimental treatments contained the following features:

1. A list of warm-up items consisting of five foreign countries presented as stimuli and their capitals as response items.
2. A typing test which recorded the student's time and accuracy in typing an alphabetic sentence consisting of 74 computer characters.

3. A progress report to the student after each cycle consisting of:
    a. total number of responses;
    b. total number of stimuli presented;
    c. total number of items acquired;
    d. total response latency;
    e. current clock reading.
4. An automatic 5-minute break approximately halfway through the task.
5. An automatic connection to a system-administered student opinion survey (SOS) regarding CAI.

Subjects

On the basis of variability data collected during a pilot study, it was estimated that a minimum of ten subjects in each experimental group would be needed for statistical purposes. A total of 24 students from the Williamsport Area Community College and the Altoona Campus of the University were included in the study and were randomly assigned to the experimental treatments. Proctors who administered and supervised the students at these locations were given specific instructions to read to the students participating in the study.

CAI proctors from the two campuses solicited volunteers to participate in the experimental study. The students were told that the study would require a maximum of four hours and that they would be paid a flat rate of $5.50 regardless of how much actual time it took them to complete the study. The students were randomly assigned to one of the experimental treatments. The proctors assisted the students with the initial registration procedure. The students' typeouts were returned to the course authors for analysis.

The following summarizes the variables and their parameters which were of concern in this study:

1. Pretest, posttest, and retention tests: all contained the same items--the names of the 50 states of the United States with a possible high score of 50 and a possible low score of 0.
2. Total number of stimuli presented: fifty stimuli (state names) were presented to each subject on the first cycle through the material. Those to which he responded correctly on his first attempt were not presented again. Those to which he responded incorrectly were retained and presented again during the next cycle of the program. The minimum number presented was 50; the maximum was unlimited, determined by each subject's performance.

3. Total number of responses during instruction: each time a stimulus was presented a response was required from the subject. Feedback was presented after each incorrect response and additional responses were required until the correct response was made. The minimum number of responses was 50; the maximum was unlimited but based on each subject's performance.
4. Total instructional time: includes the elapsed time from when the first item was presented until the final correct response was made.
5. Student opinion survey: a 20-item multiple choice questionnaire. Each response was weighted from five to one to produce a maximum score of 100 reflecting a strong favorable attitude toward CAI or a minimum score of 20 reflecting a strong negative attitude toward CAI.
6. Response latency during instruction, posttest, and retention test: After each stimulus item was presented a green PROCEED light turned on. The PROCEED light remained on until the subject pressed the EOB key to record his response. The time interval that the PROCEED light was on was recorded as the response latency for that item. The sum of these intervals was the total response latency accumulated during instruction, the posttest, and retention test.

Findings

There was very little difference in the two treatments based upon all of these criteria except total instructional time. Although there is some difference in the total number of states presented, there is virtually no difference in the total number of responses made in each experimental treatment. This means that in the gradient feedback treatment the student was responding more often to the same stimulus, but it was not necessary to present the stimulus as often as was required for the students in the full-response feedback program.

An adjusted analysis of variance using the pretest scores as a covariant was performed on total instruction time. The pretest correlated -.847 with total instructional time. The analysis produced an F-ratio of 15.3 which was significant beyond the .01 level. For the analysis of the posttest data, the pretest scores and the typing scores were used as covariants in an analysis of covariance. A Kuder-Richardson formula 20 reliability estimate of .725 was found for the posttest. The pretest correlated .468 with the posttest; the typing test correlated .403 with the posttest. The adjusted analysis of variance for the posttest scores resulted in an F-ratio of less than unity.

An adjusted analysis of variance was also performed on the retention test scores (Kuder-Richardson formula 20 reliability estimate of .893) using the posttest and the typing test as covariants. The posttest correlated .675 with the retention test, and the typing test correlated .592 with the retention test. This analysis resulted in an F-ratio of 1.44, not significant at the .05 level.

Conclusions

Although the treatment comparisons did not show statistically significant differences in learning, there was a very strong difference in instructional time for the two treatments. The response latencies also show rather striking differences between the two treatment groups and hold some promise for directing future research. The anticipated advantage for gradient feedback over full-response feedback did not materialize in this study. We are well aware that additional investigations will be required before discarding the theoretically sound idea of providing learners with a graduated feedback.

Because of the problems encountered with remote locations it was not considered advisable to engage in further statistical analysis of the data although they do suggest a trend. Silberman, Melaragno, Coulson, and Estavan (1961) conjectured that some measures such as response latency are more appropriate than error rate for making certain decisions within a program. Postman and Egan (1949) point out that reaction time remains a sensitive measure of the readiness of an organism to respond. Using data of this kind has always been a difficult process because of the technical problems involved in measuring response latency and feeding the information back into the operating system for decision-making purposes. However, with the development of computer-assisted instruction and the speed and flexibilities of such systems, this information is readily available and can easily be used for making such decisions. It is the intent of the authors to continue investigating these variables which seem to hold promise for improving learning with computer-assisted instruction.

A Comparison of the Effectiveness of Five Feedback Modes in A Computer-Assisted Adjunct Auto-Instruction Program

Rationale

Intuitively, it seems probable that the correction of errors in a program should be beneficial to the student and that an efficient mode of feedback for correcting errors can be developed. This study used materials designed to teach widely misunderstood general science concepts (Gilman, 1967). Errors made by the subjects occurred as a result of misconceptions they had acquired in previous conventional instruction. It was thus possible to correct Ss' errors without teaching them erroneous material and without intentionally tricking them into committing errors.

Subjects

Subjects for the study were 75 students in teacher preparation curricula (science teaching excluded) at The Pennsylvania State University. Ss were students in audio-visual classes and had no previous experience with computer-assisted instruction.

Materials

An adjunct auto-instruction program was prepared to teach commonly misunderstood general science concepts. The frames of the program were multiple-choice items. One response to each item was a correct response, one response to each item was a common misunderstanding of the concept, and the other two responses were plausible distractors.

The program caused all of the items to be presented on the first iteration and all items missed on the first iteration to be repeated on the second iteration; all items missed on the second iteration to be repeated on the third iteration, until the subject had answered all of the items correctly. Criterion for the program was a correct response to each of the thirty items.

Procedure

Seventy-five subjects were assigned to fifteen strata on the basis of scholastic aptitude examination scores. Five Ss in each strata were randomly assigned to one of five treatment groups: a) no feedback; b) knowledge of results feedback; c) knowledge of correct response feedback; d) response contingent feedback; e) a combination of b, c, d feedback.

Independent Variables

Analysis of variance performed on data obtained from the scores of Ss on The Pennsylvania State University Scholastic Aptitude Examination (obtained from University files prior to the study) showed no differences between treatment groups at the .05 level of significance. Analysis was made of the correct response scores attained by Ss immediately following the first iteration of the 30-item program (the pretest). No significant differences were found among treatment groups.

From this evidence, it may be concluded that there were no differences among the treatment groups with respect to scholastic aptitude, or to prior knowledge of the concepts.

Rate of learning. In terms of the results obtained during the second iteration and during the time spent by Ss to reach criterion, there were strong indications that Ss who received feedback guiding them to the correct response were learning more effectively and performed better than did those who were forced to "discover" the correct response. The means of groups C, D, and E are significantly better at the .01 level of significance than those of groups A and B on the following criteria:

Number of correct responses to second iteration of program
Number of responses required to attain criterion
Number of iterations of program required to attain criterion
Accumulated response latencies on second iteration of program

These results and their level of significance clearly indicate some of the advantages to be gained by instructing students with a feedback mode that guides them to the correct response.

The results of these comparisons indicate the value of providing information to students during a programed instruction sequence. The findings are in agreement with those of Holland (1965) who concluded, after analyzing several studies, that if a student does not know the correct answer, he might as well be told it.

However, Klaus (1965) in describing the point of view of those programers using the knowledge of results technique stated that they found no advantage in showing the correct answers to learners who provide incorrect responses. Klaus states, "Simple substitutes, such as the statement, 'you are correct' should prove equally effective as a confirmation of the correct answer." In other words, Klaus holds that the appearance of a correct answer serves as reinforcement only when the response is correct; otherwise, the response is wasted.

The poor results demonstrated by the knowledge of results feedback group (Group B) in the present study raise questions as to whether this mode of feedback is adequate for an adjunct auto-instructional program. Most of the studies involving adjunct auto-instruction have utilized knowledge of results feedback and have only informed the S whether his response was correct or wrong. This type of feedback has been utilized in many types of teaching machines. Data from the present study, however, indicate that providing a student with a statement of which response was correct, or providing him with a statement of why the correct response was correct would be of more value than merely telling him "correct" or "wrong."

From the analysis of the means of all of the variables in this study, it is interesting to note that there was little difference between the means of the knowledge-of-results feedback group and the no feedback group. In none of the variables analyzed was there a significant difference at the .05 level between means of groups A and B.

In the comparisons cited in the first part of this section as being indicative of the advantage of using a feedback mode which guides the S to the correct response, there were no significant differences between groups C, D, and E. Apparently the factor which accelerated the learning of Ss was "being informed as to which response was the correct one." In all of these comparisons, however, the mean of Group E, the combination of feedback modes group, was only slightly, but not significantly better than the means of groups C and D, and in all cases, significantly better than the means of groups A and B. This finding is contrary to those of Swets and his co-workers (1962) who found that "fairly extensive feedback may be detrimental." However, Swets *et al*. used a small step programed instructional sequence which resulted in few response errors.

The findings of the present study are in agreement with those of the previously cited study by Bryan and Rigney (1956). Although Bryan and Rigney found response contingent feedback to be superior to knowledge-of-results feedback, they made no comparison of these feedback modes with knowledge of correct response feedback.

The results of the present study clearly demonstrate some of the inefficiencies of using a "discovery" approach in teaching facts or concepts by an auto-instruction program. Those _Ss_ who were required to discover the correct response demonstrated poorer performance than did those _Ss_ who were merely told the correct answer.

Time required for instruction. The results from the time required to complete the first interation showed clearly that those treatment groups which received long feedback messages (groups D and E) required significantly more time to complete the thirty items in the first iteration than did groups A, B, or C. The time to criterion means show that Group C required significantly less time than did groups D or E, and required the least time of the five treatment groups.

The time required for a student to receive instruction by CAI is a function of the number of instructional frames he completes and also is a function of the amount of time the terminal spends displaying messages. Several studies have demonstrated that the operating speed of the IBM 1050 terminal is slower than would be ideal for an interface between student and computer. The longer feedback messages require much more time because of the slow (120 words per minute) typing rate of the terminal. However, the new interfaces using CRT display devices display verbal and graphic material much more rapidly than does the typewriter terminal. Therefore, the additional time required by _Ss_ in groups D and E should be interpreted with caution, since better equipment may soon eliminate those observed differences in instructional time.

The analysis of the data from the first and second iteration of the program and during the entire sequence indicate that the principal difference between the treatment groups is in rate of learning. Rate of learning may be considered in terms of the amount of instruction that must be presented or in terms of the amount of time required to complete the instruction. When rate of learning is considered in terms of amount of instruction presented, then a feedback method which guides the student to the correct response is clearly superior to a feedback method which requires the student to discover the correct response. When learning rate is measured in terms of the amount of time required for instruction, a feedback method utilizing short messages requires less instructional time per frame than does one utilizing long feedback messages. However, this difference may be eliminated as better interfaces between computer and student are designed.

Retention. The analysis of variance on posttest scores indicated that the combination of feedback modes group (Group E) was superior to other feedback and no feedback groups. Apparently the amount of information the S derives from the feedback is important in affecting retention.

Because many of the programs used in previous studies have been of the linear low-error-rate variety, little work has been done to ascertain how to deal with errors committed by the student during a program. There have been few studies dealing with "corrective" feedback in verbal learning. One study found that providing the correct answer following an incorrect response is a reinforcing event in the same way that confirmation after a correct response is a reinforcing event. The results of the present study indicate the advantages for learning attained by providing the correct response when the S makes an error and also show the retention advantages of providing the S with as much information as possible in the feedback messages. These findings disagree with some studies that found that extensive feedback may be detrimental.

Results obtained from the posttest also indicate some differences favoring the response contingent feedback groups. On the posttest, the response contingent feedback group (Group D) received the second highest scores and scored higher than any other treatment group receiving a single feedback treatment.

Group D accumulated significantly higher response latencies during the first iteration of the program and during their performance criterion. Apparently the Ss receiving response contingent feedback were contemplating their previous feedback messages during the time period that they might have been responding.

Relationship between analyzed variables and scholastic aptitude. Analysis of variance showed only one significant difference for level effects--instructional time for the second iteration of the program. There was no apparent pattern in the means of strata for the admissible probability score on the first iteration of the program, but examination of the time to criterion means for the 15 strata reveals a negative relation between scholastic aptitude and time for the second iteration.

A low correlation between Ss' rate of learning and academic ability is one of the desirable characteristics of computer-assisted instruction as expressed by Mitzel. Mitzel hypothesizes that computer-assisted instruction

> . . .at its best should offer a distinctly individualized course of instruction in which gaps in the learner's knowledge are filled by means of diagnostic and remedial sequence steps. Thus, it seems to be theoretically appropriate to ask the typical CAI learner to achieve mastery of the content as long as we allow him a reasonable amount of time. (Mitzel, 1966)

Mitzel concluded that if examining is done at appropriate intervals throughout the program, then every learner should have achieved mastery of the content up to the limits of his capacity.

Further research is necessary to determine the effects of using various modes of feedback to correct errors. Many forms of programed instruction require the student to reveal, by making some sort of error, the kind of instruction he should receive next. However, most typical programed instruction studies have been conducted with relatively error-free programs and little is presently known about correcting student errors in programed instruction.

The present study should be repeated using a student terminal capable of faster communication and response time than the 1050 terminal.

Also, the present study should be repeated using a delayed retention measure in addition to the immediate retention measure.

The high posttest scores achieved by all groups, including the control group, demonstrated the value of reiterating the program items until the student had answered all items correctly. Several studies have demonstrated the value of providing feedback on test items. The results of the present study indicate that an additional advantage can result from having an S repeat all unanswered questions until he has correctly responded to each one. This procedure provides a "drill" type of exercise in a test situation in addition to providing feedback.

Effect of CAI on Natural Spelling Behaviors

Rationale

Although a field trial had indicated that the CAI spelling course was an effective means for two-year technical students to learn spelling, no attempt had been made to examine whether the students transferred their increased knowledge of spelling rules (as indicated by criterion scores) to off-terminal, non-test writing situations. Consequently, the investigation of transfer was selected as the primary focus of the present study (Farr and Hogan, 1967).

It was assumed that after the diagnosis and identification of spelling errors, followed by remedial instruction, students would spell more accurately than they had in non-test, writing situations before instruction. Further, it was assumed that students who were merely informed of the number and kinds of spelling errors that they had made on the pretest would show less improvement in non-test, writing situations than the students who had been given the same information and also received prescribed remedial instruction. Accordingly, the main dimension investigated in this study was the difference in the extent to which the instructed students transferred their demonstrated spelling skills, in contrast to those who had not been instructed.

Method

The materials used in this study were of three types: a) two samples of expository writing done by the students on topics they selected from a list provided; b) selected segments of the CAI spelling program; and c) a 44-item attitude questionnaire about CAI.

The topics for these writing samples were deliberately planned by the authors to center the attention of the students on the thought content of their writing, rather than on spelling or other mechanics of composition. Furthermore, no mention of spelling was made when the writing assignments were given, and the attitude questionnaire was concerned with CAI and the students' reactions to it, rather than to any aspect of spelling.

From the CAI spelling program, all of the students were given three segments on-line: orientation, word study, and the diagnostic test. The first segment was a short one dealing with orientation to the terminal equipment and its operation. The second segment provided the students with further opportunity to familiarize themselves with appropriate on-line procedures, as well as preparation for maximum benefit from spelling study. The diagnostic segment consisted of a 37-word test which included 50 possible error items representing nine categories of spelling errors. For example, the word "piece" was designated as both a possible homonym error and as a possible "i-e" error.

In addition to these three segments, the students in the experimental group took the on-line instruction prescribed by their diagnostic test performances, and a 37-word 250-item, on-line posttest similar to the diagnostic test.

The 48 students participating in this study were enrolled in post-high school, two-year technical programs. The experimental group consisted of 23 students; the control group contained 25 students. Two of the experimental students were women; one of the control students was a woman.

Results

The effectiveness of transfer from this CAI spelling program was assessed on two dependent measures: a) performance on the spelling pretest and posttest (minimal transfer); and b) performance on two writing assignments (remote transfer).

Spelling test data for the experimental students were analyzed within a 2 x 2 factorial design (two student groups x two test scores and/or pretest and posttest scores) with repeated measures on one factor (pretest and posttest). The results of this analysis indicated that there was a significant improvement in spelling test performance on the CAI posttest ($p <.05$). However, when absolute criterion performance was examined, it was found that the experimental students had entered the program performing at a 66% level of accuracy, and their end-of-program criterion performance was only 76%. These results indicate that some learning had occurred, but that the students' difficulties with spelling had by no means been entirely eliminated.

Conclusions

The main conclusions from this study to investigate the effectiveness of transfer from this CAI spelling course were: a) students in two-year technical courses demonstrated a significant improvement in their spelling abilities as measured by spelling tests, after they had received instruction from this CAI program; and b) when they were not specifically told, on writing assignments, that "spelling counts," post-high school technical students made far more errors in certain categories than they made in those categories during test situations.

Because, for the non-test writing samples gathered in this study, students were free to use--or not to use--any words they wished, it is reasonable to conclude that the ones they used are the words they "need" to know how to spell: the very words that formal spelling instruction aims to teach. Likewise, the large number of errors appearing in the writing samples can be taken as an indication of the failure of traditional, classroom spelling instruction to achieve its commonly stated goal of teaching "needed" words.

The novelty of CAI experience and the appeal of its technology for students in technical courses did not produce a markedly greater amount of transfer of spelling ability to non-test situations than had other methods of instruction earlier in the students' educational experiences. This, however, should not be regarded as failure of this CAI course. Unanimously, on the attitude questionnaire students indicated that they felt that spelling was a subject that could be effectively taught by CAI, and their scores indicate that it was. Since, CAI does not seem to affect their spelling in general writing situations any more than any other method of instruction, it might be of particular value to consider the ways in which students--and teachers--approach spelling instruction. Such consideration is recommended if the present CAI course is revised in the future.

Perhaps, if adults who are in need of remedial spelling are to be "all-around" competent spellers, the spelling course must include an attempt at attitude change, so that spelling is accepted as a skill with "all-around" importance. Otherwise, for many students, and especially for students in technical courses, spelling is likely to remain a subject in which students do as well as possible only on spelling tests and in situations where they know that "spelling counts."

Comparability of Computer-Assisted and Conventional Test Administration

Purpose

The purpose of the research reported here was to compare conventional group administration and computer-assisted administration of a test of creativity (King and Rabinowtiz, 1968).

Method

Two separate studies were conducted using different Ss and slightly different procedures. They used the same basic measures and analysis, however, and thus may be presented together. Study I was a preliminary effort to the larger, more extensive Study II.

Subjects

Study I used 37 paid volunteer male technical education (two-year program) students enrolled at The Pennsylvania State University. Random assignment was made to either a computer-assisted or a conventional test administration condition. Study II used 107 (36 men, 71 women) volunteer undergraduates enrolled in baccalaureate programs at The Pennsylvania State University. Ss within each sex were randomly assigned to the two test conditions to insure equal proportions of men and women under each condition.

Analysis

The problem of determining whether computer-assisted testing and conventional testing are directly comparable is really a problem of determining the equivalence of two forms of the same test--one administered by computer and the other by conventional procedures.

Medley (1957) has proposed a procedure for testing the equivalence of two tests which examines four criteria: equality of means, equality of variances, equality of errors of measurement, and "homogeneity of function." The procedure is based upon a two-factor analysis of variance with repeated measures on one factor, and is especially appropriate for use in studies of the type reported here where carry-over effects necessitate the use of different subjects for the two test forms (or in this case two modes of administration).

In the present experiment, the Medley test for equivalence was applied in both Study I and Study II to compare the performance of the computer-assisted and conventional groups of the Remote Associates Test (RAT) Form I. The two administration modes coupled with the 30 items of the RAT resulted in a 2 x 30 factorial design, with repeated measures across subject. In the Medley procedure each of the four criteria for equivalence (equal means, equal variances, equal errors of measurement, and homogeneity of function) can be stated as a null hypothesis, and if any are rejected the tests in question cannot be regarded as equivalent. If all four null hypothesis cannot be rejected then the overall hypothesis of equivalence may be accepted. The four F-ratios corresponding to the four hypothesis were calculated and tested for significance in both studies.

Additional correlational analyses were performed in Study II to determine the existance of possible differential relationships between the two administration modes of the RAT Form 1 and the four reference measures. Pearson Product-moment Correlation Coefficients were calculated between each of the reference measures and each mode of administration of the RAT Form 1, and all pairs within administrations were tested for significant differences with z-transformations.

Results

The means and standard deviations for all administrations compared favorably with those reported by Mednick and Mednick (1967) in the normative data for college undergraduates. Hoyt internal consistency reliability estimates, calculated from the analysis of variance format used for the Medley procedure, were found to be slightly lower than odd-even split-half coefficients reported by Mednick and Mednick.

One noteworthy comparison that can be made is the high degree of similarity between the performance of the technical education Ss in Study I and the baccalaureate program Ss in Study II. Students enrolled in two-year technical education programs are generally believed to be less intellectually capable than four-year students. Although many variables were uncontrolled between Studies I and II the results would appear to indicate that in at least one dimension of intellectual functioning the two-year students compare quite closely with four-year students.

Table 4

Medley Equivalence Analysis
Analysis of Variance: RAT Form 1

Source	Study I df	Study I MS	Study I F	Study II df	Study II MS	Study II F
Conventional Administration						
Subjects	17	1.00	1.37[a]	53	.88	.81[a]
Items	29	.80		29	1.99	
Error	493	.19	1.00[b]	1537	.19	1.06[b]**
CAI Administration						
Subjects	18	.73		52	1.08	
Items	29	1.04		29	2.57	
Error	522	.19		1508	.18	
Combined Groups						
Subjects	36	.85		106	.99	
Items	29	1.63		29	4.18	
Error	1044	.19		3074	.19	
Analysis for Testing Equivalence						
Administrations	1	.26	.29[c]	1	1.32	1.34[c]
Subjects (within administrations)	35	.87		105	.98	
Items	29	1.63		29	4.18	
Error Between	29	.21	1.10[d]	29	.38	2.11[d]**
Error Within	1015	.19		3045	.18	

[a] F ratio formed by comparing MS for subjects under conventional administration with MS for subjects under CAI administration. Actually a test for homogeniety of variance.

[b] F ratio formed by comparing MS for error under conventional administration with MS for error under CAI administration. Actually a test for homogeniety of the variance of errors of measurement.

[c] F ratio formed using subjects within administrations as a conventional error term. A test for equality of means for the two administration conditions.

[d] F ratio formed using error within administrations as a conventional error term. A test for homogeniety of function which compares the rank order of item difficulties for the two administration conditions.

** $p < .01$

The Medley equivalence analysis and the calculation of the F-ratios used to test each of the four equivalence criteria necessitated dividing the overall analysis of variance into separate analyses representing each mode of administration, and an analysis representing the combined administrations. The first criterion of interest, equality of means for the two administration modes, was tested by comparing the variance between administrations with the variance for Ss within administrations. The resulting F-ratios for both studies were nonsignificant, indicating failure to detect differences with respect to the mean performances under the two modes of administration. The second criterion, equality of variances, was tested by forming an F-ratio from the mean square for subjects in each of the separate mode analyses. Again, the F-ratios for both studies were nonsignificant, and the conclusion is that the variances for the two modes of administration are not reliably different. The third criterion, equality of measurement error variances, was tested by an F-ratio formed from the error terms in each of the separate mode analyses. Here a significant F was obtained for Study II, but since the value of the F was only 1.06 with 1537 and 1508 df the difference is probably not of great consequence. Thus, the criterions of equal error of measurement variances also appears to be reasonably satisfied. The final criterion, homogeneity of function, was tested with an F-ratio formed by comparing the error between administrations with the error within administrations. A significant F was obtained for Study II indicating that the item difficulty rankings were not the same for both modes of administration. Items proving very difficult under computer administration were apparently slightly easier under conventional administration and vice versa. The resulting conclusion is that in Study II the RAT Form 1 was not measuring identical functions under the two modes of administration.

Additional correlational analyses performed in Study II resulted in correlations between each of the administrations of the RAT Form 1 and each of the reference measures correspond (in the case of the first three reference measures) roughly with those reported by Mednick and Mednick. The correlations between the RAT Form 1 and the RAT Form 2 are slightly lower than reported in the Test Manual. The fourth reference measure, Flexibility, does not appear to correlate with the RAT. All four correlation pairs between administration modes were tested for significance, and none of the differences proved significant. Thus, there is no evidence to indicate that the parallel forms reliability or the validity of the RAT are any different under computer administration than under conventional administration.

In summary, the study reported here does not present any evidence to indicate that computer-assisted test administration introduces new sources of variance that markedly modify the statistical properties of a test as determined through conventional administration.

Numerical and Verbal Aptitude Tests Administered at the CAI Student Station

Purpose

The purpose of this study (French and Tardibuono, 1968) was to arrange tests using multiple choice, numerical, and verbal items, in a program so that:

1) the average number of items attempted by each student will be significantly less than the number of items traditionally required by a test of similar content (in this case, the *Henmon-Nelson Test of Mental Ability*);

2) the test will take significantly less time to administer than the traditional test;

3) indices of reliability obtained by means of internal consistency formulas (KR 20) will be higher for COMPAT (Computer Administered Test) than for those reported in the manual for the *Henmon-Nelson* tests; and

4) there will be a significantly high correlation between each COMPAT and the *Henmon-Nelson Test*, and between each COMPAT and student performance in other academic activities.

The Sample

One of the practical limitations encountered in the first phase of this project was the availability of subjects of the appropriate age and educational level willing to take time for research projects. Since this project focuses on the feasibility of developing short, highly reliable tests, vocational-technical school subjects were not sought. The 73 subjects used in this reporting period included high school juniors and seniors, housewives, and undergraduate and graduate students from Penn State. It should be noted that 80 subjects took the various tests. However, systems difficulties and loss of subjects reduced the number to 67.

Procedure

Each subject took five tests: 1) the Henmon-Nelson College Level, Form B, 2) Verbal 80, 3) Numerical 80, 4) Pretest, and 5) Verbal A, B, C, or D. The directions for the Henmon-Nelson are contained in the test booklet which each subject read himself. For the COMPAT tests, each S was shown how to operate the terminal, how to respond, and how to correct a mistake. He was instructed as follows:

> You will be shown questions, either verbal or mathematical on the screen at your left. As soon as you have the answer, type the number indicating that answer, then press EOB; the next question will then be shown. If you wish to change an answer before you press EOB, follow the procedure previously described. Remember once you press EOB you will not be able to change your response. There is a time limit for each question; but if you work steadily, you need not rush. I will be in the next room if any complications arise. Any questions? You are now ready to begin.

Due to the length of time necessary to complete all five tests, most of the subjects returned for a second session. The availability of computer time as well as consideration for the subject's schedule made exact intervals between sessions impractical. Each subject was paid a flat rate of $3, unless system failures necessitated returning for a third session in which case payment was made at the rate of $1.25 per hour.

As each S entered the terminal room, he was given either the Henmon-Nelson College Level, Form B, the pretest, or assigned to one of the computer-administered tests. Due to the varying lengths of time subjects spent on each of the tests, it was not practical to randomize the order of the tests.

Results

To achieve goals 1 and 2 required the administration of relatively few items in a relatively short period of time when compared with the administration of the conventional format of the Henmon-Nelson. In conventional format the Henmon-Nelson test provides 100 items and allows no more than 40 minutes of working time. While not all subjects attempt the 100 items, it is assumed that as subjects run into difficult items they scan the remaining items in hopes that they can find some which they can answer. With the COMPAT procedures, the mean number of items attempted varied from 23 to 30 and the mean number of minutes varied from 21 to 31. Relatively large standard deviations were observed for both number of items attempted and time spent on the test. The objectives of constructing a test with fewer administered items than on the criterion test was realized. When the numerical test and verbal test were added together, a mean of 57 items was obtained.

Time was obtained by subtracting "sign-on" time from "sign-off" time. The figures include minor system delays and program malfunctions. By analysis of the response latencies of a random sample of 25 subjects, it was learned that the time to complete the test is decreased significantly when only response latencies to each item are considered.

Goal 3 pertains to reliability. At this stage of development with these tests, test-retest procedures over short periods of time did not seem appropriate. Statistical formulas requiring that the same items be presented to each subject were inappropriate also since the same pattern of items was presented to few subjects. Since great care was exercised in the selection of items arranged in order of difficulty, it was assumed that all items which were not administered and which were below the score would have been passed. It was further assumed that all items which were not administered and which were above the subject's score would have been failed. Since these assumptions are implicit in the computation of the score, it is reasonable to assume them also in the computation of reliability coefficients. (Such procedure is followed in the administration of such tests as the Stanford-Binet.)

It should be noted that Kuder-Richardson formulas yield slightly higher correlations than other methods of measuring reliability and that the technique of assigning a minus or a plus to unanswered items will tend to inflate the obtained correlations. The Kuder-Richardson coefficients ranging from .977 to .988 compare favorably with the odd-even reliability coefficients of .94 and .95 reported in the technical manual for total scores of the college level Henmon-Nelson tests. The technical manual reports alternate form reliability coefficients of .84, .876, and .887 for Q, V, and total scores. Thus, it is concluded from the first phase of the reliability study that a highly reliable test can be adapted for presentation by a computer.

The final area of investigation to be reported here involves a comparison between COMPAT and the conventional Henmon-Nelson test. The relationship between COMPAT and the conventionally administered Henmon-Nelson test are not as substantial as those reported in the Examiner's Manual for alternate forms of the Henmon-Nelson.

It was evident from the data that the normative data for the Henmon-Nelson cannot be used to interpret COMPAT scores. Norms will need to be developed if COMPAT scores for individuals are to be interpreted.

It should be noted that the number of subjects who took COMPAT Verbal-C or Verbal-D was dependent on their score on the pretest. Since COMPAT Verbal-A and Verbal-B were administered to only 10 subjects, correlational data for those tests were not computed.

Remedial and Review Branching in Computer-Assisted Instruction

Purpose

There are two basic kinds of branching strategy. The first is to branch the student to an alternate sequence of remedial material. The second is to provide the student with a review or re-exposure to material he does not yet understand.

The purpose of this investigation (Gilman and Gargula, 1967) was to compare the effectiveness of branching strategies in an instructional program prepared for computer-assisted instruction with that of a nonbranching CAI program.

Method

The subjects were 42 students from the tile setting and plumbing programs of Williamsport Area Community College, Williamsport, Pennsylvania. These students were selected because they had not previously received instruction in physics. All were naive with respect to educational experimentation procedures.

Subjects were randomly assigned to two proportional groups. The linear group consisted of 14 Ss and the branching group consisted of 28 Ss. The randomization was accomplished by the use of a well-shuffled stack of student data cards. Ss were pretested with the 10-item pretest. No S answered more than four questions correctly, and most answered all questions incorrectly.

The linear group received only the instructional frames of the program. The branching group received the instructional frames and corresponding remedial frame when an incorrect response was emitted during the instructional frame, but also reviewed segments of the program on which they had a high error rate.

Response latency, or the time required for the student to answer a question, was recorded by the computer for each response and was accumulated during the instructional period. The total instructional time was also recorded by the computer.

Immediately following the instruction, the 25-item posttest was administered to each subject.

All instruction was "stand alone" instruction in that no other instruction was provided other than the programed course.

There were slight differences in the means of the posttest favoring the branching group and a slight difference in instructional time favoring the linear group. These small differences were not statistically significant ($P > .10$), but they do suggest the need for further study of this variable in CAI mode.

One important factor in comparing the programs was the number of responses required in the program. The difference in the means of the group were significant ($P < .001$). Clearly, more responses were required by the branching group than by the linear group.

It is interesting to note that although the branching group required more responses to complete the program, the mean response latency was less than that of the linear group, so that differences between the means of the total accumulated latencies for the two groups were not significant (P <.10). The lower latencies perhaps resulted from a greater amount of practice in using the terminal interface.

Discussion

The major conclusions of the study may be summarized as follows:

1) No differences in achievement were obtained for a CAI program which incorporated instructional frames, branching to remedial frames, and review of program segments over a program which presented only instructional frames.

2) As a result of a criterion established by the programer, the students in the branching group required significantly more responses to complete the program. However, this learning strategy resulted in no noticeable gains in learning.

3) Although the branching group required significantly more responses to complete the program, the mean response latencies of the linear group were lower than those of the branching group. Thus, there were no differences in the total accumulated response latencies for the two groups.

Conclusion

The results of the present study appear to be consistent with the results of Holland (1965), Campbell (1961, 1962), and Glaser (1962) in that no advantages were found for a branching strategy.

The results are not consistent with those found by Skinner (1961) and Holland and Porter (1961). Evans (1965) and Barlow (1963) who have found the controversy of "linear vs. branching" to be one which cannot be answered unequivocably, since the two instructional techniques serve different functions.

The results of this study indicate that if branching is to be used to advantage in computer-assisted instruction, there must be a thorough investigation of those situations where it facilitates learning. Also, research needs to be implemented to determine the criteria for branching decisions.

Relative Effectiveness of Various Modes of Stimulus Presentation Through Computer-Assisted Instruction

Purpose

The purpose of this study (Johnson and Borman, 1967) was to determine the relative effectiveness of the various modes of presentation on total time for students to complete the course and on competence as determined by a posttest score.

Based on selected studies, it was hypothesized that the static display mode of presentation would take significantly less time and result in as equally effective learning as the typewriter-output mode of presentation since the static display mode presents a paragraph of material to a student at a time and allows him to proceed at his own pace. The material chosen for this study was a basic physics sequence or "Working with Units." The instruction was designed for vocational-technical students who have finished high school and have a limited background in mathematics and physics.

Subjects

The Ss consisted of 90 upperclassmen majoring in education and taking Instructional Media 435 at The Pennsylvania State University during the Fall Term, 1966. Each S in the Instm. 435 class was required to spend one hour at the CAI student station. The Ss were randomly assigned to one of four groups. (Due to computer malfunction and scheduling problems, the final groups did not contain equal numbers.) None of the Ss possessed a background of study in mathematics or physics prior to the treatment.

Procedure

Type Mode. The S signed on the course, the computer typed out instructions followed by questions. After the S typed his answer, the computer proceeded by typing material to the S, showing slides, typing questions, etc., until the lesson was completed. The S was immediately tested on his knowledge by a 15-item, multiple choice, computer-administered test. Total instructional time and test scores were recorded.

Audio Mode. Ss who received instruction through the audio mode heard the same material that the Ss in the previous mode read from the typeout. Ss could repeat each message as often as desired. They also received some typed material and slides which were common to all groups. When finished, they took the same computer-administered test. Total instructional time and test scores were recorded.

Display Mode. Ss in the display mode had a booklet containing all of the messages heard by the above group. Instead of hearing the messages as the above group, the typeout instructed them to read the proper page of the booklet. This group also received the same typed material and slides as the above groups. The same computer-administered test was taken by this group and their total instructional time and test scores were recorded.

Control Group. Ss in the control group received no instruction, but took the same computer-administered test as the above groups. Only their total test scores were recorded.

Findings

An analysis of variance procedure gave the results shown in Table 5. The F-ratio was significant beyond the .05 level of confidence. Sheffe's procedure for multiple comparisons (Sparks, 1963) showed that the audio, type, and display modes of presentation were all significantly superior to the control group concerning posttest scores. There were no significant differences between the audio, type, and display modes.

The above finding suggested to the authors that there may have been too much overlap between the type mode and the other modes since 39 out of 55 frames were common to all groups in stimulus mode. This commonality may have hidden any mean differences in completion time. In order to remedy this situation, the authors decided to run the experiment again, this time increasing the number of frames containing variable modes of presentation.

Subjects

The Ss consisted of 87 upperclassmen majoring in education and taking Instructional Media 435 at The Pennsylvania State University during the Winter

Table 5

Means and Standard Deviations of Posttest Scores
(Maximum Possible Score 15 Points)

Mode	N	Mean
Type Mode	12	11.17
Audio Mode	16	13.00
Display Mode	12	11.67
Control Group	50	8.90

Term, 1967. Each S in the Instm. 435 class was required to spend one hour at the CAI student station. The Ss were randomly assigned to one of four groups. The Ss did not have a mathematics or physics background.

Implications

The purpose of this experiment was to examine the question of decreasing instructional time on-line through various modes of presentations without a decrease in learning.

Special note should be taken of the findings indicating that the mean scores on the posttest for each experimental group was significantly higher than the mean score on the posttest for the no-instruction control group. It should also be noted that there were no significant differences on posttest score among the experimental treatments (audio, display, type, and slide). This was a consistent finding in both experiments. Therefore, regardless of mode of presentation, all groups were able to learn from the programed sequence.

The main purpose of the experiment, to decrease instructional time on-line, did not result in significant findings. However, there are some interesting tendencies which warrant further investigation.

An Experimental Procedure for Course Revision Based on Students' Past Performance

Purpose

In an earlier study the researchers had investigated the time required to complete a program under various modes of stimulus presentation. No significant differences were demonstrated between the various modes because of the large variances obtained in the dependent variables for the various modes. At that time it was the intent of the authors to analyze each subject's performance on each frame in order to determine whether or not there were certain frames in the program that contributed a large proportion of variance to the total within groups variance. This study (Borman and Johnson, 1968) was an attempt to improve the program.

Method

Upon completion of revisions, the course originally titled, "Working With Units," contained 47 frames including six slides common to all modes of presentation. The sequence was designed so that all Ss received four warm-up frames, each frame presented in a different mode, the main purpose of which was to acquaint each S with the correct method of terminal operation. Following the introductory material, 43 frames of material were presented for which data were collected and analyzed.

In order to provide for a variation in stimulus modes, four versions of the course were created. The material from the 37 frames (not including slide material) was presented four ways. One group received this material on audio tape to provide the audio mode of presentation. One group received this material printed on charts and put together in a booklet, each page of which contained the material from one frame of the program. The program instructed the Ss to read a given page. This mode of presentation provided the chart display mode of presentation. In a third version of the course, the type mode, the material was typed to the student on the typewriter associated with the IBM 1050 computer terminal. The fourth group received the instructional material on 2 x 2-inch photographic slides; the material was identical to that contained on the audio tape, chart display group, and typewriter output. All groups received identical versions of the course and all groups were required to answer the questions by typing their answers on the typewriter keyboard at the terminal.

A 20-item constructed-response test was created. The test was designed to measure factual material as presented in the program as well as a subject's ability to transfer what he learned to similar problems. For example, in addition to dividing meters by seconds, a concept taught in the course, the Ss also had to divide ficticious units such as dividing "yens by fuds." Since the program was not designed to teach computational skill, it was decided to score the test only on the basis of whether or not the S had the correct units, not whether or not the S had the right numerical answer. The Kuder-Richardson Formula 20 reliability of this test was .862.

Subjects

The Ss consisted of 33 volunteer upperclassmen majoring in education and taking Instructional Media 435 at The Pennsylvania State University during the Fall Term, 1967. The Ss were randomly assigned to one of the four experimental treatments. The Ss did not have a mathematics or physics background. In addition another group consisting of 90 upperclassmen majoring in education and taking Instructional Media 435 at The Pennsylvania State University during the Fall Term, 1967, served as a naive control group and took only the posttest.

Procedures

Each S signed on the course and was presented with the instructional material and questions based on the material. The S responded to the questions by typing his answer on the typewriter keyboard. Feedback material was presented by the computer to all Ss via the typewriter. Upon completion of the course, Ss were administered a 20-question constructed-response test off-line. Total for each question, the response latency for each response, and the number of correct responses on the posttest were collected for each subject.

Results

The main purpose of this experiment was to test a procedure for course revision based on past performance. Graphs were prepared to indicate weak sections or frames in the course based on high mean response latencies and/or high mean numbers of attempts. The graphs also indicated frame-by-mode-of-presentation interactions, i.e., indicated frames where one mode of presentation was superior or inferior to the other modes of presentation. It is felt that by examining these interactions, it may be possible to indicate which mode of presentation should be used for which purposes as well as how to best use a medium for a specific purpose. For example, it was found that, for the given course material, it was necessary to keep the audio messages relatively short.

In revising the course, care was taken to improve those frames which contributed large proportions of variance to large mean response latencies and the high mean numbers of attempts. The revisions would tend to make the course more uniform and easier for all groups, since all versions of the course were improved, a condition reflected by the minute mean differences for total time to complete the program. A possibility for future research would be to revise only the frame for the modality which experienced difficulty, leaving the other frames unchanged. Diagnostic revisions may serve to lower within group variance and capitalize on the differences that are inherent in the various modes of stimulus presentation available with CAI.

The course material used in this experiment is the product of a number of revisions after it had been carefully written by a subject matter and programing expert. Even now, it is far from being optimally efficient and effective stimulus material to promote student learning. There are still many peaks and valleys that must be accounted and compensated for through revisions or branches. The most significant finding to date is that course development is a complex, time-consuming process which must be carried out in a context where student performance data are continually used as a basis for subsequent revisions.

Expressed Student Attitudes Under Several Conditions of Automated Programed Instruction

Purpose

Due to the rather general finding that student attitude and performance measures tend to be only moderately correlated, it cannot be assumed that a program which results in satisfactory criterion performance will necessarily result in a positive student attitude. If it is granted that student attitude may have significant effects on students' behavior after the period of instruction, it seems that a different approach to the study of student attitude is called for. Rather than studying the effect of student attitude on criterion performance, research should be directed to developing instructional programs which achieve both satisfactory criterion performance and positive student attitude. In this experiment (Brown and Gilman, 1967) student attitude was treated as one of the outcomes of instruction.

Method

The subjects were 66 ninth and tenth grade students in the college preparatory curriculum of State College Junior High School. All were naive with respect to educational experimentation procedures, and none had received instruction in physics. All *S*s who began the experiment completed it.

Three programed courses were prepared. The subject of the three programs was dimensional analysis, or performing calculations involving units of measurement in working physics problems. The material of all three programs was identical with the following exceptions. The first program (CPF) was a CAI program utilizing contingent prompting and feedback. The second (KCR) was also a CAI program, but feedback consisted of the knowledge of the correct response. The computer typed the correct response two inches to the right of the student's response as in a typical programed text. The third group (text) received instruction which contained feedback material identical to the KCR program, but was presented by a programed text rather than by a computer controlled terminal.

Design

Subjects were randomly assigned to three groups. The randomization was accomplished by the use of a shuffled stack of student data cards. *S*s were pretested with the ten-question pretest. No *S* answered more than three questions on the pretest correctly and most answered all questions incorrectly.

In all three groups the instruction was completed in a single session. All instruction was "stand alone" instruction in that no other instruction was provided other than the programed course. There were no difficulties with any of the equipment used during the experiment and the CAI groups experienced no down time or delays on the hardware.

Test

Student attitude was measured by a 40-item Likert-type scale, previously developed at The Pennsylvania State University CAI Laboratory.

Student responses were scored 1 to 5, with 5 being the response which indicated the most favorable attitude toward the instruction. The maximum attainable score was 200. Kuder-Richardson formula-20 reliability obtained during an earlier study was .885.

The attitude scale was administered to each S following the session of instruction.

Results

The responses of each student to the 40 items on the attitude scale were summed to yield one score for each student. The data were analyzed within a two-factor, treatments by sex, analysis of variance design. The only significant difference found was between the three-treatment means ($F = 12.89$, $df = 62$, $P < .001$). Scheffe's "S-test" was performed on the three group means. This analysis showed that both KCR and CPF means were significantly different ($P < .01$) from the text group. The KCR and CPF were not significantly different from each other ($P > .05$).

Groups KCR and CPF scored significantly higher on the attitude inventory than did the text group. There were no significant differences between the KCR group and the CPF group. There were no differences attributable to sex.

The differences between groups receiving computer-assisted instruction and instruction by programed text are similar to the anticipated results. The differences in attitude scores cannot be attributed to differences in performance as the three groups did not differ significantly on either posttest or retention test performance. The groups did differ on the amount of instructional time required; however, in this experiment there seems to be no basis for explaining attitude in terms of time per se. Apparently the more positive expressed attitude computer-assisted instruction as compared to the attitude expressed toward programed texts is attributable to student preference for a novel automated instructional medium.

In the opinion of the authors the approach to the study of student attitude suggested in this report and illustrated by the above experiment should be employed, in conjunction with, if not instead of, the typical correlational approach, in research aimed at the development of instructional programs which achieve both satisfactory criterion performance and positive student attitude.

Effects of Reducing Verbal Content In Computer-Assisted Instruction Programs

Purpose

This study investigated the effects resulting from reducing the verbal content in a CAI program. The rationale for this treatment is that those students of low verbal ability may comprehend material better when taught by programs with short, concise sentences containing few unusual words, rather than when they are taught by programs with a high verbal content.

This study (Gilman and Harvilchuck, 1967) tested three hypotheses regarding the verbal content of computer-assisted instruction programs. The expected findings were as follows:

1) A low verbal content program requires less instructional time than a high verbal content program.

2) Greater comprehension (posttest performance) results from having studied a low verbal content program, as contrasted with having studied a high verbal content program.

3) There is a higher correlation between achievement (posttest performance) and verbal intelligence (*California Test of Mental Maturity*) for students studying a high verbal content program than for students studying a low verbal content program.

Method

The subjects were 36 students from the tile setting and plumbing programs of Williamsport Area Community College, Williamsport, Pennsylvania. The students were selected because they had not yet demonstrated high academic ability and had not received previous instruction in the content materials (significant figures) to be used in the study. All *S*s were naive with respect to educational experimentation.

Ss were randomly assigned to two treatment groups of 18 Ss per group. Ss were pretested with the five-item pretest. No Ss answered more than two questions correctly and most Ss answered all questions incorrectly.

Both treatment groups received instruction through the 1050 terminal. The time required for instruction was recorded by the computer. Immediately following the instruction, the 18-item posttest was administered.

Conclusions

The major conclusions from this study may be summarized as follows:

1) It is possible to substantially reduce the verbal content of a computer-assisted instructional program without significantly decreasing the learning which results from a student having studied the program.

2) The conditions in which instruction is presented by a low verbal content program required significantly less time than instruction by a high verbal content program. This effect results from the slow type-out rate of the typewriter terminal device and the additional time required by students to read and comprehend the longer typed messages.

3) Although the difference between the correlation of achievement and verbal intelligence was not significant, the results indicated a slightly higher correlation between intelligence and achievement on the part of the students who studied the low verbal content program.

Reducing the verbal content of a computer-assisted instruction program has definite advantages for efficiently utilizing instructional time. The time saving can be considerable when a typewriter interface is used. There are also advantages for using low verbal content programs with the newer CRT interfaces, since these devices cannot accommodate lengthy messages.

The use of low verbal content materials may also be advantageous for the slow learner. Further studies should be conducted with a wide variety of programed materials and with larger groups of subjects to ascertain whether or not the lower correlations of achievement and verbal intelligence on the part of the students studying low verbal content programs can be replicated.

The widespread use of programed materials is advantageous to students of all ability levels, but particularly to low ability and less literate students. For many low ability students, studying materials that are programed may mean the difference between comprehending the material and being confused. It is recommended that there should be a greater effort to program materials with as low a verbal content as is possible in order that low ability students can more adequately comprehend the programs.

Prior Knowledge and Individualized Instruction

Purpose

This research (Brown and Bahn, 1968) was designed to investigate a possible technique for adapting to individual differences, specifically for adapting instructional methods to the extent of prior knowledge.

If a program is to be responsive to the needs of students who have various amounts of prior knowledge, it should possess the following:

1. a means of assessing each student's knowledge of each concept or sub-concept prior to instruction;
2. a means of skipping past material which the student has already mastered;
3. a means of providing a rapid review of the material about which the student has some prior knowledge;
4. a means of providing instruction on the material for which the student has little or no prior knowledge.

An effort was made to provide these four capabilities in a CAI program.

Three separate techniques were employed in an effort to prepare a program which would be adaptive to the needs of students possessing various amounts of prior knowledge.

Subjects were randomly assigned to each of two programs, 33 Ss were assigned to the Experimental Segment (EXS), and 32 to the Modern Mathematics Segment (MMS). Subjects were run individually on IBM 1050 terminals. Each subject was administered a 22-item pretest immediately before going on the program, a 22-item posttest, and an 11-item transfer test immediately following his completion of the program, and a 22-item retention test one week later. The pre-, post-, and retention tests specifically included conversions from one base to another, which were taught in the program. The transfer test required the Ss to perform addition and subtraction in bases other than base ten. All four tests required constructed responses. The reliability estimates for the respective tests by Kuder-Richardson Formula 20 are as follows: pretest, .93; posttest, .93; transfer test, 93; retention test, .96.

Results

Students who received non-zero scores on the pretest or who had received prior instruction on numbers systems other than base ten were categorized as having prior knowledge (PK) of the content. Students who scored zero on the pretest and had received no prior instruction on numbers systems other than base ten were categorized as having no prior knowledge (NPK) of the content. Performance data, consisting of posttest, transfer test, and retention test scores along with instructional time, were analyzed within a 2 x 2 analysis of variance design. One factor consisted of program (MMS or EXS), the other of extent of prior knowledge (PK or NPK).

The results of the analysis of variance of posttest scores for the PK and NPK groups indicated that neither of the main effects were significant; however, there was a marginally significant interaction between extent of prior knowledge and program taken ($P < .10$).

The results of the analysis of variance of retention test scores for the PK and NPK groups by program are very similar to the results of the analysis of posttest performance. The main effect for programs was not significant. The main effect for extent of prior knowledge was significant ($P < .05$); however, as on the posttest, there was a marginally significant interaction between extent of prior knowledge and program taken ($P < .10$).

The results of the analysis of variance for the transfer test scores show no significant differences in retention test performance.

The analysis of variance results for instructional time indicated a significant main effect for programs ($P < .05$). The main effect for extent of prior knowledge as well as the interaction was non-significant.

Because of the marginally significant interaction between program taken and extent of prior knowledge for posttest and retention test data, the simple main effects were calculated. From analysis of the simple main effects, the following pattern emerges. PK Ss on EXS do significantly better than NPK Ss ($P < .05$) for the posttest, and ($P < .01$) for the retention test. Ss on MMS having PK do not do significantly better than Ss having NPK ($F < 1.0$).

The simple main effects of PK - NPK across MMS - EXS are as follows: for Ss having PK there were no significant differences in performance on posttest or retention test attributable to the instructional programs (F <1.0). Ss having NPK did significantly better on MMS on both posttest (P <1.0) and retention test (P <.10).

The EXS program seems to have capitalized on the knowledge which Ss had prior to instruction. The finding of no significant differences between MMS and EXS on posttest, transfer test, and retention test, coupled with the time saving for EXS, suggests that students with prior knowledge would benefit by having instruction on EXS rather than MMS. For NPK Ss the lower posttest and retention test scores on EXS seem to call for MMS for these Ss in spite of the time saving on EXS.

Discussion and Conclusions

The procedure reported here seems to provide a means of adapting to extent of prior knowledge which results in considerable time saving with no decrease in criterion performance. The results of this study also suggest that neither of the programs could be recommended for all students if they vary widely in extent of prior knowledge. Perhaps parallel programing employing the formats of both the programs with a branching procedure for switching students from one program to the other may provide the benefits of both.

The procedure employed in EXS may have somewhat limited application in terms of the instructional content. The content in this study was such that a student's prior knowledge of a concept could be evaluated. For content consisting of more or less discrete units of information, evaluation of prior knowledge by the method employed here may not be feasible.

Response Latency: Its' Relationship with Errors and Response Stability in Two Tasks Involving Response Competition

Purpose

The present study (Berman and Villwock, 1969) was designed to investigate the relationship between response latency and the tendency to make an error, rather than a correct response, and the tendency to make a stable, rather than an unstable response.

The following expectations were proposed:

1) Students would make more errors and have longer response latencies on problems which involved a high degree of response competition than on those with little response competition.
2) Students would have longer test and retest response latencies for problems on which the response was changed from the test to the retest than for problems on which the response remained the same.
3) In the present study problems were designed so that they would be of varying difficulty, with both the error response tendency and the correct response tendency varying in strength. However, some instructions and examples of correct responses were given, so that the correct response tendency was probably either stronger than the error tendency or, if it was weaker than the error tendency, it was at least moderately strong. It was, therefore, expected that the response latency for errors would be longer than the response latency for correct responses.

Method

Fifty-three college undergraduates from two introductory courses were enrolled in the experiment as paid volunteers. There were 30 men and 23 women. Students were told that they would be paid a flat rate for serving in the experiment in two sessions.

The same computer program was administered to students twice, with a six to eight day interval between the two tests. Students were given instruction and practice using the light pen and typing and entering responses. They were told to answer as soon as they thought they knew the correct answer and that both speed and accuracy were important. The two keys used to enter responses were covered with red tape and referred to as the "red keys" in an attempt to facilitate discrimination and shorten response time. Introductory and instructional frames remained on the interface until the student indicated his readiness to proceed by pressing the red keys.

Results

The results confirmed two of the study's hypotheses, and were equivocal with respect to the third.

Students made more errors and had longer response latencies on problems which involved more competition between responses than on those with less response competition. This was true with both types of problems even though in each, response competition was varied in a different manner.

In the set tasks the number of responses which appeared relevant to problem solution were varied. Single dimension problems could be solved by simply attending to the one feature of the stimuli on which the two choice figures differed. In contrast, the critical feature of the multi-dimension problems could be any of a number of dimensions on which the choice figures differed. In order to solve the multi-dimension problems students were required to attend to each of these stimulus features until they found the critical feature. In the base problems, the degree to which overlearned habits from base 10 were in conflict with new responses associated with other base systems, varied.

The results are perhaps more clearcut for the base problems than for the set problems, since the difference between the response latencies of single and multi-dimensional problems failed to reach significance on the retest. In constructing the set figures there were no controls for perceptual variables. Instead, perceptual differences were randomly distributed among single and multi-dimension problems since the ten sets of stimuli were randomly assigned to the two conditions. Perceptual factors were undoubtedly a source of significant variability in errors and latency among the five single dimension problems, and among the five multi-dimension problems. A possible means of controlling for these differences would be to construct two sets of choice figures for each problem, thus creating a single and a multi-dimension form of each problem, each to be administered to a different group of students.

Students took longer to produce errors than correct responses on both types of problems. The differences were highly significant and were not due to the fact that errors and long latencies were both associated with significant factors such as test vs. retest, single vs. multi-dimension problems, or type of base question asked. These factors had been equally weighted in calculating students' average latencies for correct and incorrect responses.

In the set problems two response alternatives were given; in the base problems students produced a response from an unlimited number of alternatives, although the two strongest response tendencies were presumed to be the correct response and the response which would be correct in the base 10 system. Of course, other responses were possible and were, in fact, made. It is interesting that these other error responses were also associated with longer latencies than correct responses.

Although numerical base instructions were held to a minimum, they were obviously sufficient to establish the correct response as a strong competitive response. If it were not so, there would be little competition between the correct response and base 10 habits, and "quick errors" based on strong base 10 habits would probably have been made. After subjects produced each number in a series they were told the correct response. Subjects made many errors at the power changes. However, the time taken to produce numbers at power changes increased with each power change up to the third or fourth in the series. This increase in response latency coincided with decrease in the number of correct responses produced by the group.

The procedure used in the present experiment was more like the usual school situation in which some instructions are given, so that the correct response becomes a strong, if not dominant, response. However, it is well to remember that the positive association between error rate and latency may be restricted to situations where the error response is not in a strong dominant position.

In the set task there was no obvious relationship between error rate and mean latency for the ten problems. The correlation between error rate and mean latency for the nine base problems was .82.

It should be noted that, while students took longer to produce error responses than correct responses, students who had longer mean response latencies did not necessarily make more errors than those with shorter mean latencies and error scores on the retest, but not the test. In contrast, the relationship between mean latency and error scores on the set problems was negative (and significant on the test, but not the retest). The relationship may indicate that more care was taken by students who were more successful, and this interpretation is supported by the fact that students who spent more time looking at the instructions for the base problems took longer to respond to set problems and made fewer errors on set problems.

It was expected that students would have longer test and retest response latencies for problems on which the response was changed from test to retest than for problems on which the response remained unchanged. Mean latencies of changed and unchanged responses within six categories were compared. In all six categories the average latencies of changed responses were longer than those of unchanged responses, but the difference between changed and unchanged responses reached significance in only one category. The number of students with appropriate data to make these tests was small, particularly for the base problems. The hypothesis cannot be accepted, based on the results of the present experiment, but it is certainly worth further testing.

Prompting and Confirmation as Modes of Feedback with Computer-Assisted Instruction

Purpose

The purpose of this experiment (Borman and Hall, 1969) was two-fold: 1) to test the assumption that 16 stimulus items were of equal difficulty; and 2) to test the relative effectiveness of prompting and confirmation as two modes of feedback. It was expected that the stimulus items were not of equal difficulty; that the stimulus items would be learned in less time than when presented under the prompting mode of feedback; and that the items would be more readily remembered after varying periods of time when presented under the confirmation mode of feedback.

Method

Forty-three volunteer subjects were obtained from an Educational Psychology 14 class during the Fall 1968 term at The Pennsylvania State University. The Ss were notified that approximately two and one half hours of time would be required to complete the study; that they would be required to return to the CAI laboratory 1, 7, and 21 days after the initial training session; and that they would be paid $3.25 for their time.

Each S was randomly assigned to either the prompting or confirmation mode of feedback and trained to a criterion of 2 successive errorless identifications of the 16 stimulus materials. The Ss returned to the laboratory 1, 7, and 21 days following completion of the training session and were administered a retention test during which the Ss tried to identify each of the 6 original stimulus items randomly ordered. Before the first retention test the Ss were administered an opinion survey dealing with their experiences with CAI.

Findings

An analysis of variance procedure for repeated measures used to test the hypothesis that the 16 stimulus items were of equal difficulty. The total number of trials required to learn each stimulus item was the dependent variable. Because of the significant interaction, it was necessary to examine the simple effects, i.e., test the effect of the stimulus item at each level of feedback. The least significant difference procedure was used for each level of feedback. The items did differ significantly from each other at both levels of the factor "mode of feedback." The order of the items also differ at both levels of the mode of feedback factor. This makes it necessary to analyze the random split halves by the orders obtained from both the prompting simple effect and the confirmation simple effect. The items were arranged in descending order from most difficult to least difficult for each simple effect. Those items were marked with a P for each level of the criterion. Those items not so marked were taught by the confirmation mode. In the majority of cases, the items taught by the prompting mode of feedback were harder or easier, but not equal in difficulty, to the items taught by confirmation. Also, in the majority of the cases the items actually included in the split half were significantly different from the items which should have been included in the split half. Only those items chosen for the prompting mode of feedback at the sixth level of criterion did not differ significantly from the ideal split half.

To examine the expectation that prompting would facilitate learning, three variables; total time to criterion, total number of trials to criterion and student opinion were examined. A multivariate analysis of variance procedure produced an F of 4.80, df = 3.39, P <.01 indicating that significant differences did exist among the groups.

The Ss who learned the items by the prompting mode of feedback required an average time of 87.69 minutes (S. D. = 31.21) and an average of 7.35 trials (S. D. = 2.90) to reach criterion while the Ss who learned the items by the confirmation mode of feedback required an average time of 98.70 minutes (S. D. = 32.97) and an average of 10.55 trials (S. D. = 4.95) to reach criterion. A t of 2.54, (df = 19) was significant at .05 level for the average number of trials to reach criterion indicating that the prompting Ss took fewer trials, but the same amount of time to learn the items than did the confirmation Ss.

In addition, the student opinion scores obtained 1 day after training showed the prompting Ss to have a significantly (.05) more positive attitude toward CAI than the confirmation Ss.

The expectations that confirmation would produce higher levels of retention than prompting was tested by analysis of variance for repeated measures. Although the F = 1.18 for mode of feedback was nonsignificant, a trend did exist. Because of the tendency of the two groups to merge at 21 days, the authors hypothesized that the curves would cross after a longer period of time had elapsed after training. To test this, a fourth retention test was administered after an interval of 90 days from the time of training. Thirty-three Ss were available at that time and were willing to take a fourth retention test (N prompting = 18, N confirmation = 15). Ninety days after training, the prompting Ss missed an average of 8.6 items (S. D. = 3.11) and the confirmation Ss missed an average of 9.6 items (S. D. = 2.77). The difference was not significant, and the curves did not intersect.

Analysis of covariance procedures were used to adjust for the unequal number of trials and unequal amounts of time spent by the Ss in the various treatments. It was assumed that if a person spent more time, or required a large number of training trials, that his level of retention would be correspondingly higher. However, analysis of covariance procedures using total time to criterion and total number of trials to criterion as covariants did not change the results.

Discussion

It was shown that the 16 stimulus items were not equally difficult as assumed by Hall and Borman (1968). The data contained in this report suggest that one of two procedures be followed in further studies to avoid this error: 1) that all treatments be presented with all of the stimulus items as was done in the current study; 2) that matched groups of stimulus items be formed on the basis of the data presented in this paper. For example, once the stimuli have been ordered on the basis of difficulty, one could then assign pairwise items to alternate groups on a random basis. This procedure would assure that the two groups would have items of similar difficulty levels.

It was also shown in this paper that the prompting mode of feedback required fewer trials to master the items than did the confirmation mode of feedback even though both groups consumed equal amounts of time. This finding may be accounted for by examining the logic of the pgm. The stimulus drawing and the name of the drawing appeared simultaneously to the students in the prompting mode. The student could then spend as much time as he pleased studying the item before he typed his response and went on to the next item. However, for students in the confirmation mode, once the student typed his answer and the correct name appeared on the screen, the student only had between 8 and 10 seconds to study the stimulus and correct name together before moving on to the next item. In order for the student in confirmation mode to have an equal amount of "study time", he would be required to go through more learning trials. Amount of "study time" is a variable that should be controlled in further experiments of this nature.

The authors have also arrived at the conclusion that an additional source of variance was introduced into the task and not accounted for. Each stimulus item consisted of two concepts: A means of fastening an object (weld, flange, screw, etc.) and the object (elbow, valve, joint, sleeve, etc.). The authors currently hypothesize that students may have tried to form concepts for weld, screw, flanged, elbow, joint, sleeve, etc., instead of memorizing the name that appears with the item. This concept formation procedure by the students may have contributed an additional source of error variance, possibly hiding any effects due to prompting and confirmation as modes of feedback. In the future the authors plan to control this source of variance by keeping the means of fastening the object constant and eliminating that concept from the response. Materials are currently under development to permit the execution of this design.

Reading Rate and Retention Under Two Modes of Presentation

Purpose

The present study (Brown, Dwyer and Hollick, 1969) is focused on the investigation of one strategy for optimizing reading rate. A response sensitive external pacing technique was employed whereby reading rate was adjusted on the basis of frequently assessed immediate recall. The effects of adaptive external pacing on reading rate, immediate recall, and delayed recall were investigated. The experiment was implemented on the IBM 1500 CAI system in the Computer-Assisted Instruction Laboratory at The Pennsylvania State University.

Method

Forty-two students from introductory educational psychology and psychology classes at The Pennsylvania State University served as subjects. The students were paid for their participation in the experiment.

Procedure

Each S received 30 of the 60 passages under self-paced presentation and 30 under externally-paced presentation. Ss were randomly assigned to two groups; one group received the self-paced presentation first (SPF) and the other the externally-paced first (EPF). Within each group each S was assigned to one of four random orders of presentation of the passages.

In both the SPF and EPF conditions each passage was followed by three questions. Following the third question on each passage the S was given feedback indicating which of the questions he answered correctly or incorrectly.

In the EPF condition the student's performance was evaluated following each set of questions and on the basis of a simple set of decision rules the reading was set for the passage:

1) If the S answered all three questions correctly, the rate was incremented for the next passage.
2) If the S answered less than two of the three questions correctly, the rate was decremented.
3) If the S answered two questions correctly and if he had answered all three correctly on the previous passage, the rate remained unchanged for the next passage.

For the first ten of the 30 passages under the EPF condition, increments or decrements were in steps of 25 words per minute. For the second ten passages, steps of 15 words per minute were employed, and for the last ten passages the increments or decrements were in steps of 5 words per minute. The rate for the first passage in the EPF condition was set at 225 words per minute on the basis of data from a pilot study.

The Ss were run individually on the IBM 1510 CRT. Performance records were recorded for each Ss via the IBM 1500 student records program. Ss returned one week later and were given a 60-item retention test made up of one item from each of the 60 passages.

Results

Inadvertently 22 Ss were run in the SPF condition and 20 in the EPF condition. To achieve equal Ns two Ss from the SPF condition were picked at random and their data were excluded from the analysis.

The repeated measures analysis of variance was utilized to analyze the data. This analysis produced the following results. The externally-paced condition resulted in faster reading rates ($P < .01$). The carry-over effect of EPF coupled with what seems to have been a warm-up effect resulted in a significant interaction ($P < .05$). For the immediate recall scores, the effect attributed to differences between the two pacing conditions was significant (P <.01). The self-paced condition produced better immediate recall than the externally-paced condition. Retention test scores showed no significant differences.

While the self-paced condition did produce significantly higher immediate recall, the externally-paced condition produced significantly faster reading with no observable decrease in retention. Given this set of conditions, one should perhaps ask how important immediate recall differences of approximately four items may be, especially in light of almost identical results on retention. Perhaps the gain in reading rate in some conditions might be more important than a loss in immediate recall. The substantive significance of differences as well as the statistical significance should be considered.

Correlation coefficients for the EPF and SPF conditions were run. Several interesting and some rather puzzling observations can be made concerning the coefficients. The overall pattern is one of higher correlations in the EPF group. Response sensitive external pacing should largely rule out the effects of idiosyncratic pre-dispositional characteristics on reading rate. If a construct such as optimal information processing speed is hypothesized, then the positive correlations of reading rate with recall and retention in the EPF condition would seem to indicate that the EPF, externally-paced condition did assign Ss to rates which were appropriate. The continued positive relationships seen for EPF self-paced seems to indicate some transfer effect of the rate established in EPF externally-paced condition.

The generally low correlations under externally-paced presentation in the SPF group are difficult to explain. Perhaps starting at a rate differing from the rate established in the self-paced presentation had a disruptive effect which is reflected in the lower correlations for this group. Perhaps further light will be shed on the result by additional studies employing modifications of the decision rules employed in this experiment. Further investigation of individual difference variables in relation to rate and retention is planned.

CHAPTER VII

FLOWCHARTS

As mentioned in Chapter II, flowcharting was one of the most important activities of the project. Chapter II gives the principles of flowcharting and explains a sample flowchart. The present chapter devotes itself to a description of the instructional flowcharting strategies developed in this project. Course flowcharts, section flowcharts, and question-level flowcharts will be described. For a more complete description, see *Teaching Strategies and Tactics for Computer-Assisted Instruction*, (Dwyer, 1970).

Course Flowcharts

Strategies Informing Student About Content

Students may be able to proceed through a course with great success if they are informed about the objectives of the course. Knowing what is expected of them, the students can work effectively toward the objectives.

Objectives of course presented to student. This procedure keeps the student informed about what is expected of him and of his progress. Alternate approaches can replace presentation of the objectives of a unit with presentation of concepts that are to be acquired and skills that should be developed or the presentation of key questions the student answers (see Figure 4).

Objectives Stated Prior to Module Instruction with Option to Repeat Module. Through this procedure the student is informed of the objectives of the unit, enabling him to follow instructions more knowledgably. In addition, as the unit is summarized by modules, the student can select those he should repeat (see Figure 5).

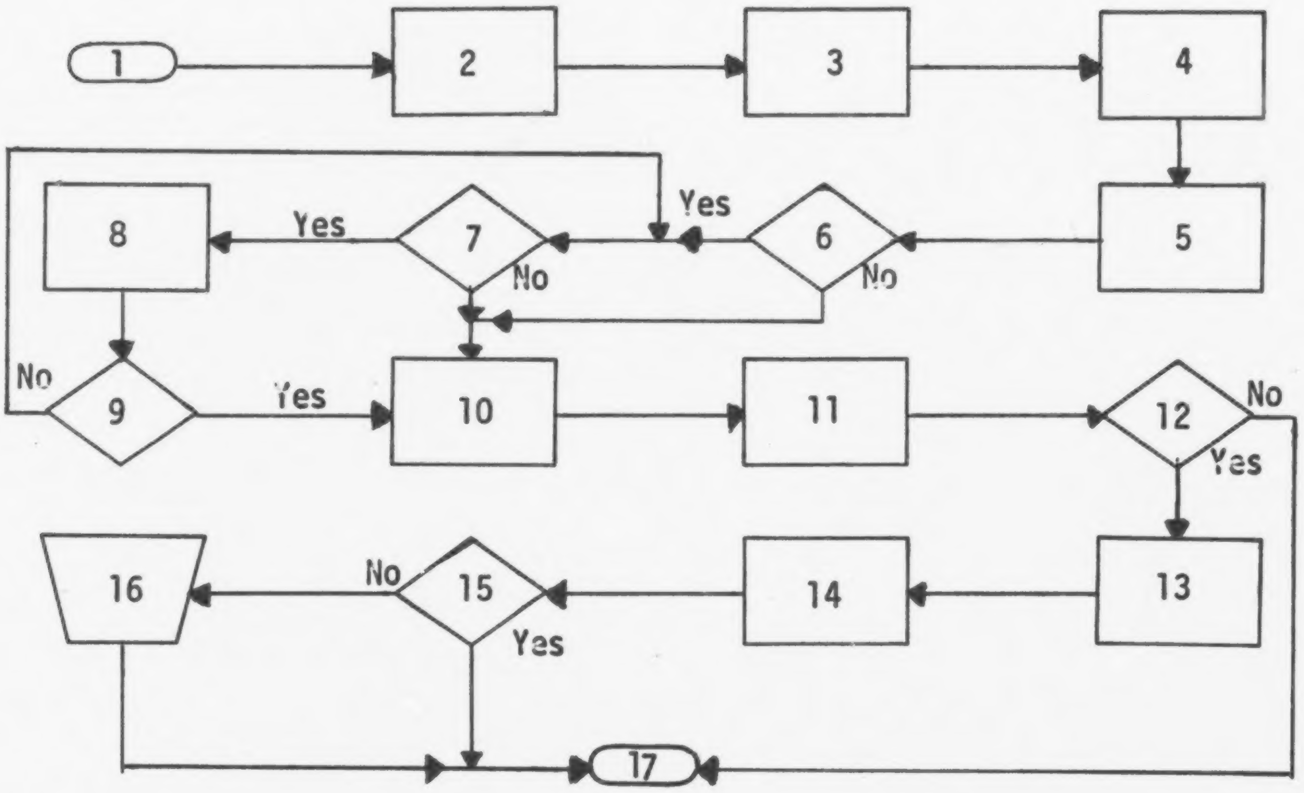
Strategies Based on Performance

A common technique in computer-assisted instruction is to accumulate data on the individual student's aptitude or his performance while taking the course and then to use this information to determine what path the student should follow.

Key to Flowchart - Objectives of Course Presented to Student

1. Start
2. Broad objectives of course presented
3. Objectives of unit n are presented to the student at the student's level of understanding
4. Instruction designed to achieve each of the objectives of unit n
5. Each objective of unit n is presented once again to the student, and he is asked to judge whether he has achieved each objective.
6. Do you want to select any sections for additional instruction?
7. Do you want additional instruction on objective n of unit n?
8. Additional instruction on objective n
9. Has student had the option to receive additional instruction on all objectives of unit n?
10. Quiz on unit n
11. Analysis of quiz results to determine which, if any, of the objectives were not achieved
12. Is remedial instruction required?
13. Remedial instruction on sections determined by results of quiz
14. Quiz questions on those sections that required remedial instruction
15. Was criterion met on the quiz?
16. Proctor message is sent to proctor station indicating the specific deficiencies of the student; off-line instruction would be given. When the student had achieved criterion on an off-line quiz similar to his most recent quiz, instruction then could proceed.
17. Next unit of course

Objectives of Course
Presented to Student


1
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5
6
Yes
No
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Yes
No
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No
Yes
10
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12
No
Yes
13
14
15
No
Yes
16
17

Fig. 4. Objectives of course presented to student.

Key to Flowchart

Objectives Stated Prior to Module Instruction with Option to Repeat Modules

1. Start
2. Objectives to be achieved in unit n are presented
3. Module of instruction in unit n
4. Is this the first time the student has received the instruction in this module?
5. Have all modules in the unit been presented?
6. Summary of unit n
7. Do you wish to repeat any of the modules in unit n?
8. Module is selected
9. Has entire course been presented?
10. End

Objectives Stated Prior to Module Instruction with Option to Repeat Modules

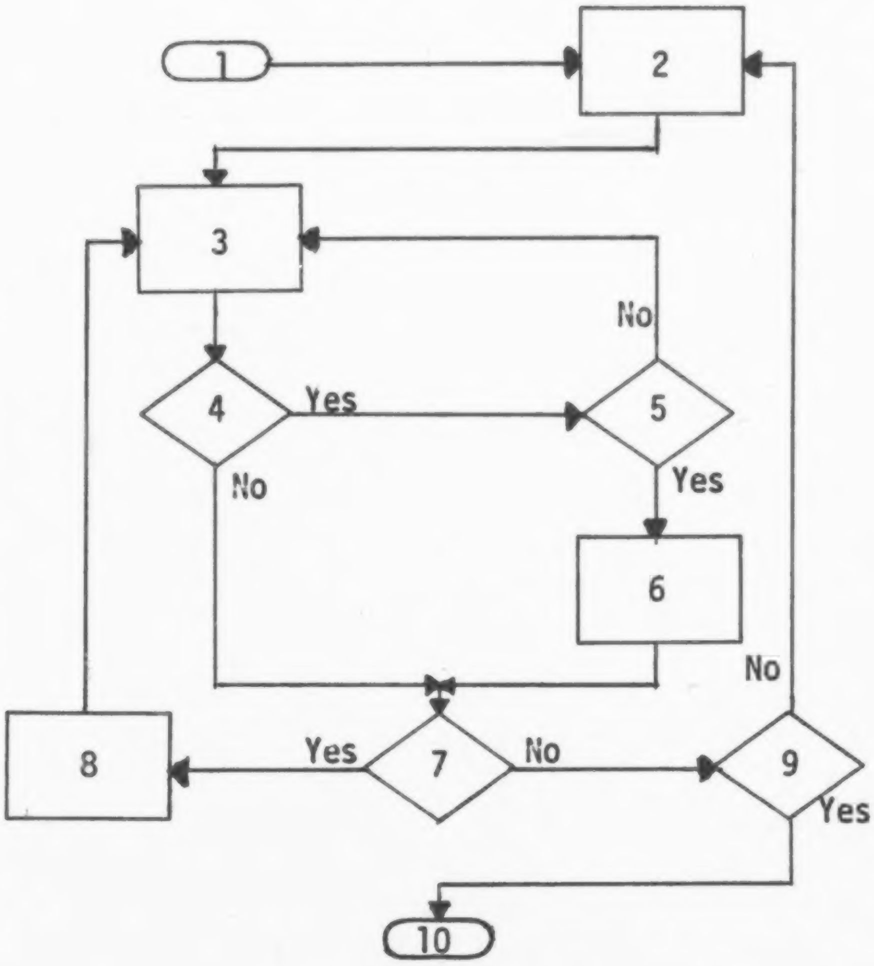
1
2
3
4
Yes
No
5
No
Yes
6
7
Yes
No
8
9
No
Yes
10

Fig. 5. Objectives stated prior to module instruction with option to repeat modules.

Sequence based on diagnostic tests. Here the student is introduced to the program, receives basic directions, and is given a diagnostic test to determine the help he needs. Based on test results he is branched to appropriate instruction, given an exercise on what he learned and a posttest to determine the extent of his learning (see Figure 6).

Course presentation in three tracks. Instruction for the below average student contains a minimum number of concepts and drill work; for the average student, basic concepts, additional concepts, and some applications of more advanced exercises; and for the above average student, all concepts, enrichment material, and advanced exercises. At specific points decisions can be made regarding the student's needs (see Figure 7).

Flexible strategy for slow, average, and advanced students. This strategy allows for slow, average, and advanced students to proceed through a course. The advanced student has the shortest and most direct route through the course. Each student receives a body of instruction and questions. Students are branched to remedial, review, or advanced materials according to performance on criterion items (see Figure 8).

Shorter sequence for better students. This procedure allows the better student to get through the material at a rapid rate, but it also presents a review of the type of material he may elect to skip (see Figure 9).

Sequence and review based on errors made. Here the student is given a choice of a quiz first. The quiz is analyzed and a branch is made depending on the number of errors. If errors are greater than an established percentage, the student is branched to instruction. If the number of errors is less than an established percentage, he is given a review of those items he answered incorrectly. If he has no errors he proceeds (see Figure 10).

Hierarchical instruction beginning at highest competency of student. This technique is used in disciplines like math and physics which lend themselves to a hierarchical design. Here the content of a course can be separated into competencies which are related in such a manner that capability in certain areas is a prerequisite for success in areas higher in the hierarchy. The course can begin with a quiz on the skills and concepts in the highest competency in one branch of the hierarchy. If criterion is met on the quiz, another branch of the hierarchy can be entered. If criterion is not met on the quiz, a quiz can

Key to Flowchart - Sequence Based on Diagnostic Tests[1]

1. Start
2. Introduction to the computer and basic directions
3. Diagnostic test to determine the concepts with which the student needs help
4. Student's score on concept n in diagnostic test is evaluated. If student understands concept n well enough to achieve the desired criterion on the diagnostic test, he is branched to further instruction on concept n (block 5). If student meets the criterion level, he is branched to the next decision point where it is decided whether or not he meets criterion on concept n + 1 (block 6).
5. Instruction on concept n
6. Have the results of the diagnostic test been used for all concepts tested?
7. An exercise is provided in which the student uses the material under study
8. A posttest similar to the diagnostic test is given and results used to evaluate student's learning
9. Stop

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[1] From Penn State's course segment Spelling, Project 5-85-074, IBM 7010 or 1410; authors: Helen L. K. Farr, Harriett A. Hogan.

Sequence Based on Diagnostic Tests

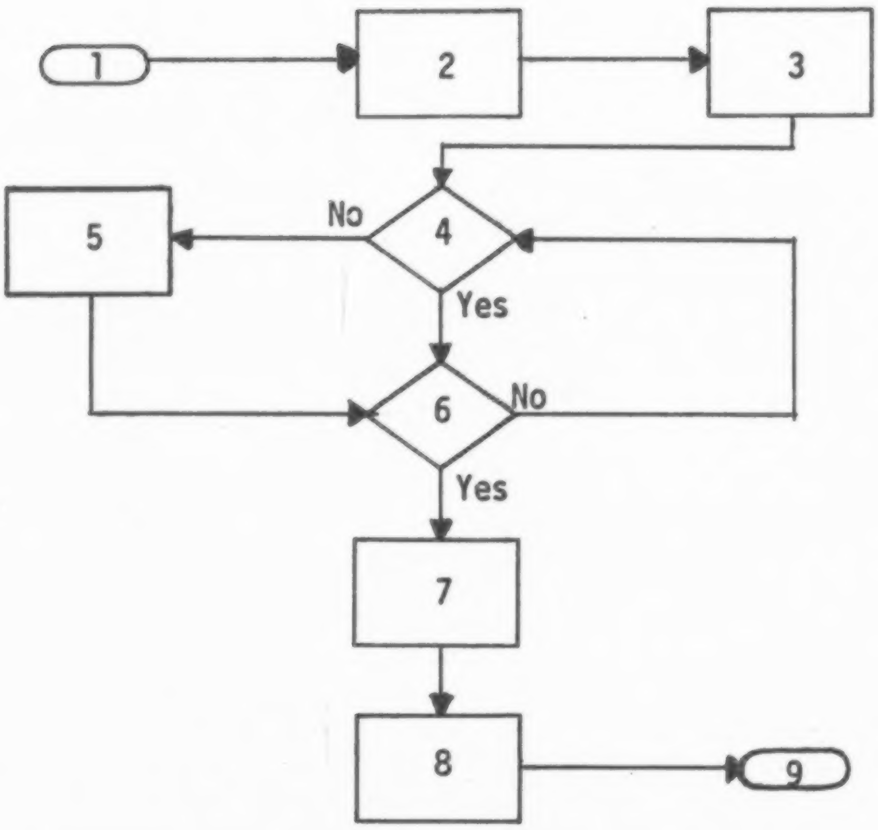

1
2
3
No
4
5
Yes
6
No
Yes
7
8
9

Fig. 6. Sequence based on diagnostic tests.

Key to Flowchart - Course Presentation in Three Tracks

1. Start
2. Analysis of pretests
3. Should instruction proceed in the track for above average achievers (track 1)?
4. Should instruction proceed in the track for average achievers (track 2)?
5. Highest level presentation (track 1) of instruction on concepts in section n
6. Criteria questions in track 1 on concepts presented most recently
7. Should enrichment activities or advanced exercises be included here?
8. Enrichment activities or advanced exercises
9. Decision is made and recorded whether the track of presentation should be lowered to average-level instruction
10. Have all sections in this unit been presented?
11. Average-level presentation (track 2) of instruction on concepts in section n
12. Criteria questions in track 2 on concepts presented most recently
13. Decision is made and recorded as to whether or not the track of presentation should be raised, lowered, or remain in the average track
14. Below-average presentation (track 3) of instruction on concept(s) in section n
15. Criteria questions in track 3 on concepts presented most recently
16. Should a recapitulation of the instruction be given?
17. Recapitulation of recent instruction
18. Decision is made and recorded whether the track of presentation should be raised or remain at the below-average presentation
19. Unit exam is given and grades are assigned by consideration of exam score and most recent track of presentation
20. End of instruction or next unit

Course Presentation in Three Tracks

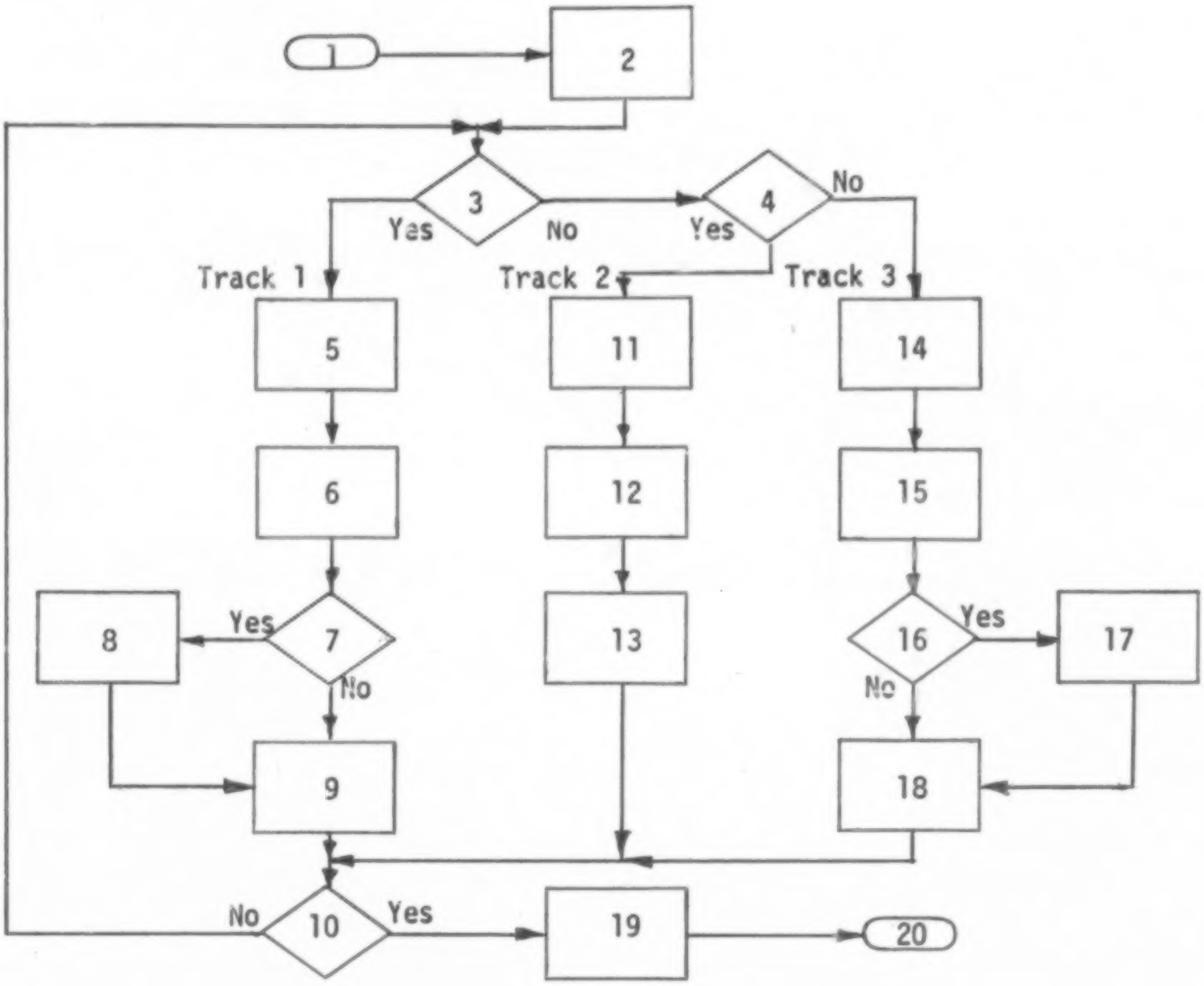

1
2
3
Yes
No
4
No
Yes
Track 1
Track 2
Track 3
5
11
14
6
12
15
8
Yes
7
No
13
16
Yes
No
17
9
18
No
10
Yes
19
20

Fig. 7. Course presentation in three tracks.

Key to Flowchart - Flexible Strategy for Slow, Average, and Advanced Students

1. Start
2. Instruction and questions on concept n for all students (slow, average, and advanced)
3. Quiz on concept n
4. Is the score on the quiz indicative of a need for review?
5. Does the score on the quiz indicate that the student has a background for advanced work?
6. Advanced instruction and questions
7. Does the student need review on the advanced instruction?
8. More advanced instruction and questions
9. Review on advanced instruction just presented
10. Review instruction and questions
11. Does the student need additional remedial instruction?
12. Remedial instruction and questions
13. Have all concepts been presented?
14. End

Flexible Strategy for Slow, Average, and Advanced Students

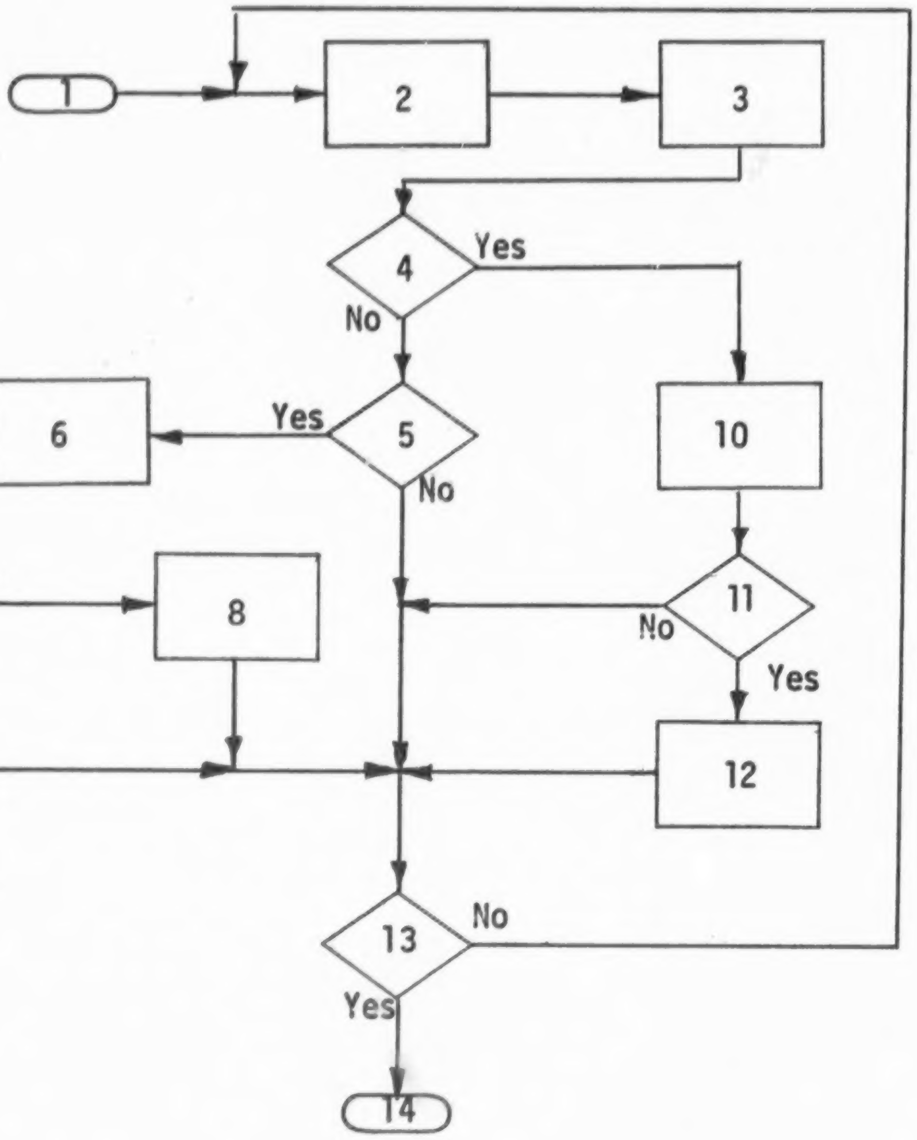

1
2
3
4
Yes
No
5
Yes
No
6
10
7
No
Yes
8
11
No
Yes
9
12
13
No
Yes
14

Fig. 8. Flexible strategy for slow, average, and advanced students.

Key to Flowchart - Shorter Sequence for Better Student

1. Start
2. Presentation of section n
3. Quiz
4. Did the student know the content well enough to proceed?
5. Rapid preview of the next section
6. Student is asked whether he would like to skip the next section
7. Is there more material to present?
8. End or test

Shorter Sequence for Better Student

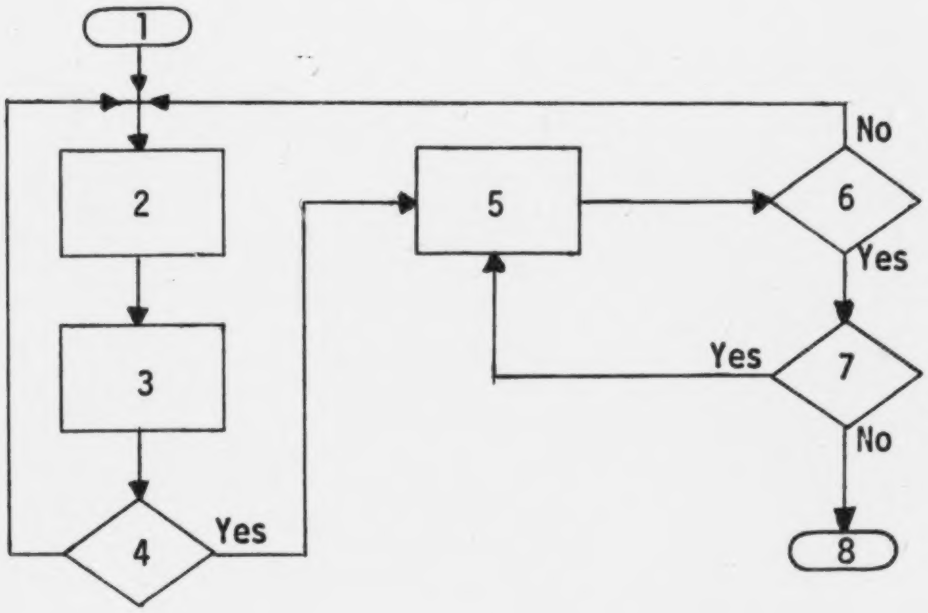

1
2
3
4
Yes
5
6
No
Yes
7
Yes
No
8

Fig. 9. Shorter sequence for better student

Key to Flowchart - Sequence and Review Based on Errors Made[2]

1. Start
2. Choice of instruction or quiz
3. Instruction which could include any number of steps
4. Quiz on instructional material from Block 3
5. Branch depending upon number of errors in quiz: (If there are no errors, student goes on to new section. If criterion was met, student is given review on the questions he answered incorrectly. If criterion was not met, student is branched back to instruction.)
6. Review is available on all questions; however, student is given review on questions he answered incorrectly
7. Continuation of course

---

[2] From Penn State's course segment Scientific Notation, Project No. 5-85-074, IBM 7010 or 1410; author: Joseph Ritchey.

Sequence and Review
Based on Errors Made

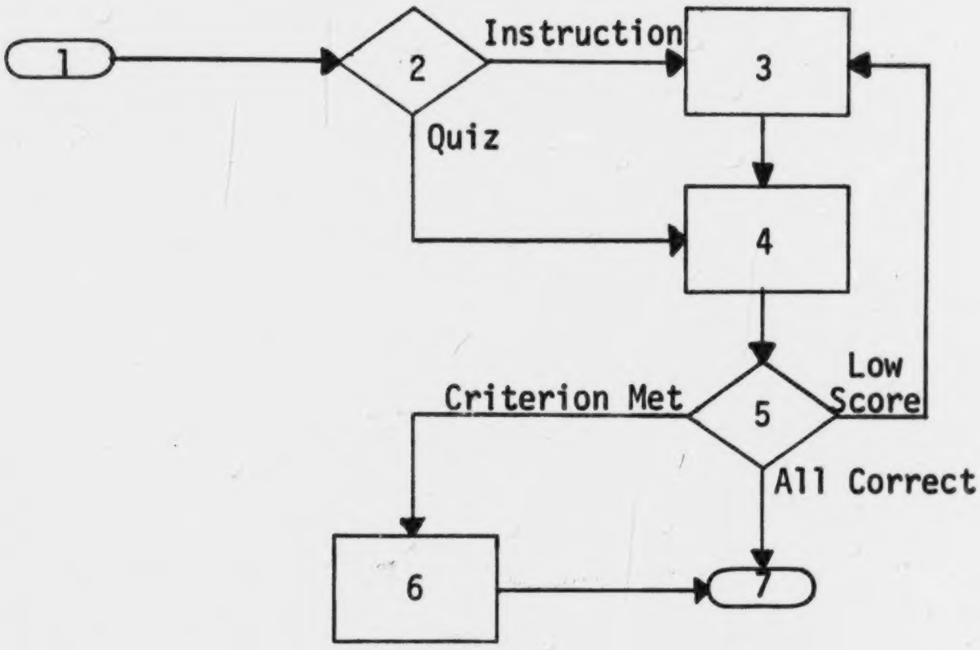

1
2
Instruction
3
Quiz
4
5
Low
Score
Criterion Met
All Correct
6
7

Fig. 10. Sequence and review based on errors made.

be administered on the next lower level of the hierarchy. If criterion is met, instruction begins at the next higher level of the hierarchy; if criterion is not met, a quiz would be administered on the next lower level until a level was found for which the student had the necessary prerequisites (see Figure 11).

Student-Selected Sequences

There are instructional sequences wherein it may be desirable to deviate from a definite order of presentation within a specified framework and allow the student to make a choice in regard to the presentation of material. Options could be to skip a section of a course, select the order to study required topics, or choose to review or not.

Student choice of additional practice or test. The student has the choice of receiving an explanation, practice problems, or a test. The only difference between doing practice problems and the test is that during the test, counters are used and the student must answer so many consecutive problems correctly in a certain period of time in order to proceed to the next section (see Figure 12).

Student given option to skip section of course. For each section, the student is given a preview and an option to skip that section. After all the sections are completed or skipped, the student is tested on those sections he selected to skip. If the test reveals insufficient competency, he is branched back to these sections for instruction (see Figure 13).

Type of sequence through course chosen by student. Student is given the choice to proceed through the regular programed sequence, a self-structured sequence, or a quiz. If he chooses the regular programed sequence, he goes through each of the concepts in order and then to the quiz. If he chooses the self-structured sequence, he can go through the instruction on the concepts and quiz questions on each concept in any order he chooses. If he chooses the quiz, he gets an opportunity after the quiz is completed to choose the concepts he would like to review. Depending upon his score on the quiz and the way in which he has chosen to go through the program, he is given various kinds of feedback. The feedback may consist of his score, an explanation of those questions he answered incorrectly, an explanation that goes along with each item under each multiple-choice question that student can choose, and a statement telling him on which concepts he has shown competencey (see Figure 14).

Key to Flowchart

Hierarchical Instruction Beginning at Highest Competency of Student

This flowchart gives the logic involved in one branch of the hierarchy of the course content.

1. Start
2. Quiz on the competencies of the highest level of this branch of the hierarchy
3. Was criterion met on the quiz?
4. Quiz for the competencies at the highest level of another branch of the hierarchy
5. Did the student come to the criterion quiz after receiving instruction at the highest level of this branch of the hierarchy?
6. Quiz on the competencies of the next lower level (level 2) of the hierarchy
7. Was criterion met on the quiz?
8. Has student received instruction at this level two successive times without achieving criterion?
9. Instruction on the highest level (level 1) of this branch of the hierarchy; (The instruction may include remedial instruction for the student passing through the instructional sequence a second time after failing to meet the criterion on the quiz.)
10. Quiz on the competencies of the next lower level (level 3) of this branch of the hierarchy
11. Was criterion met on the quiz?
12. Instruction at level 2 of this branch of the hierarchy
13. Processing may continue in one of three ways:
    a. Quiz on the next lower level of the hierarchy with the same logic being followed as the logic for other criterion quizzes
    b. Branch to another section of the course which is considered to be a prerequisite for this branch of the course
    c. Instruction at this level, which would be the lowest level of this branch of the hierarchy

Hierarchical Instruction Beginning at Highest Competency of Student

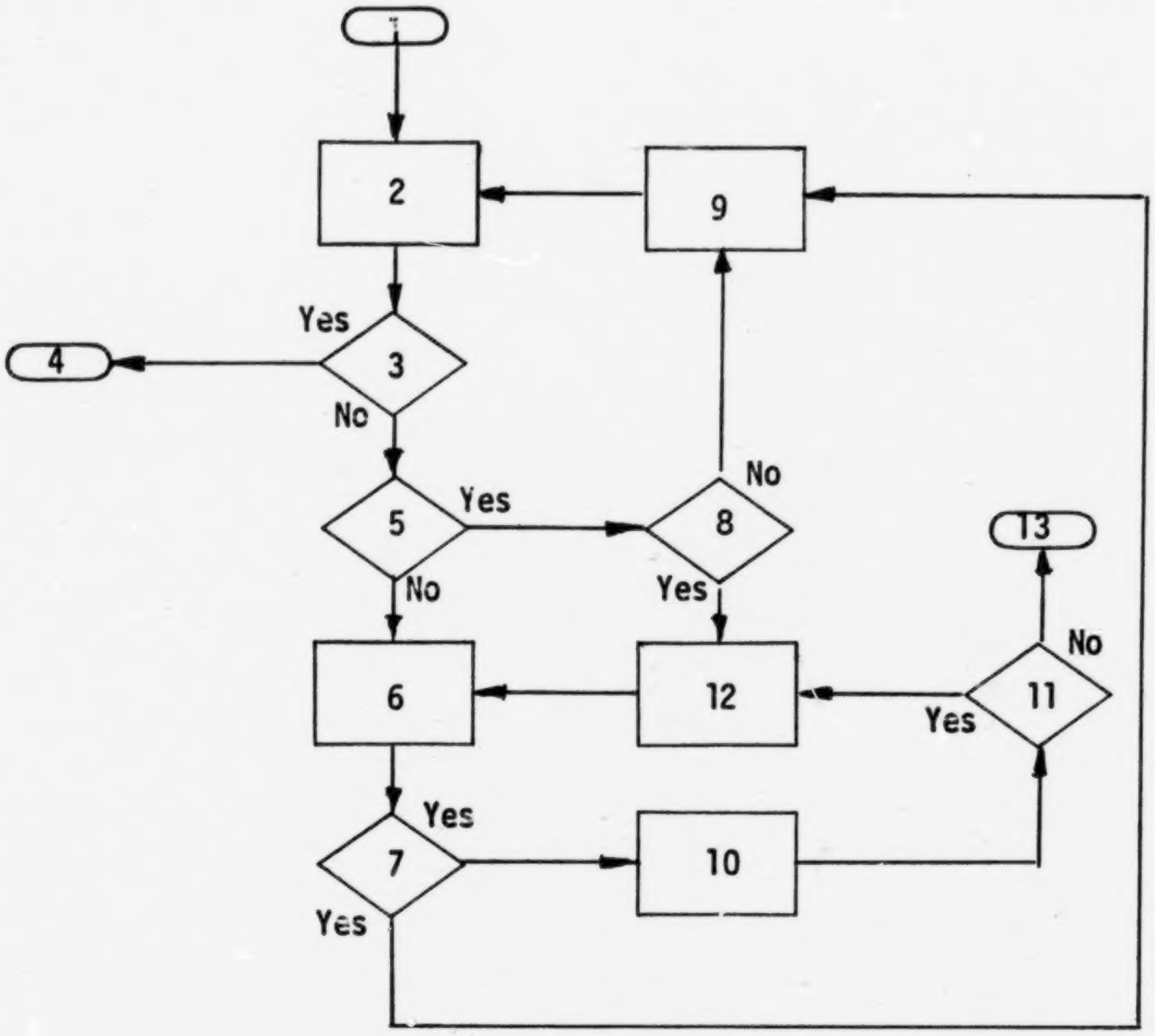

1
2
9
Yes
3
4
No
No
5
Yes
8
Yes
No
13
No
6
12
Yes
11
Yes
7
10
Yes

Fig. 11. Hierarchical instruction beginning at highest competency of student.

Key to Flowchart - Student Choice of Additional Practice or Test

1. Explanation of options available; student makes his selection
2. Did the student choose to take the test first rather than having the explanation or practice?
3. Zero is loaded into switch n which records that the student is doing problems for the test
4. Did the student choose to have the explanation of procedure?
5. Explanation of procedure is given and the student proceeds with practice problems
6. One is loaded into switch n which records that the student is doing problems for practice
7. Problem randomly generated by the computer is presented to the student
8. The student responds
9. Was the response correct?
10. Branch depending upon switches and counters; (If student is doing practice problems or has met the criterion on the test, response latency is given next. If more test problems are required, student receives a new problem.)
11. Counter used to count number answered correctly in test is incremented
12. Response latency typed out to student at end of each practice problem and end of test
13. Branch depending upon whether student is doing practice problems or the test
14. Student has choice of more practice problems or the test
15. Branch depending upon response latency on the test
16. Next section of course similar to this one
17. Initialize to zero counters and switches for student taking test in order to record how many consecutive problems answered correctly
18. Since student did not match the correct answer, the correct answer is stated along with an example of how it was arrived at
19. Is student taking test? If student is doing practice problems, he goes back to the same question and answers it again; if doing test, counters and switches are initialized to zero

Student Choice of Additional Practice or Test

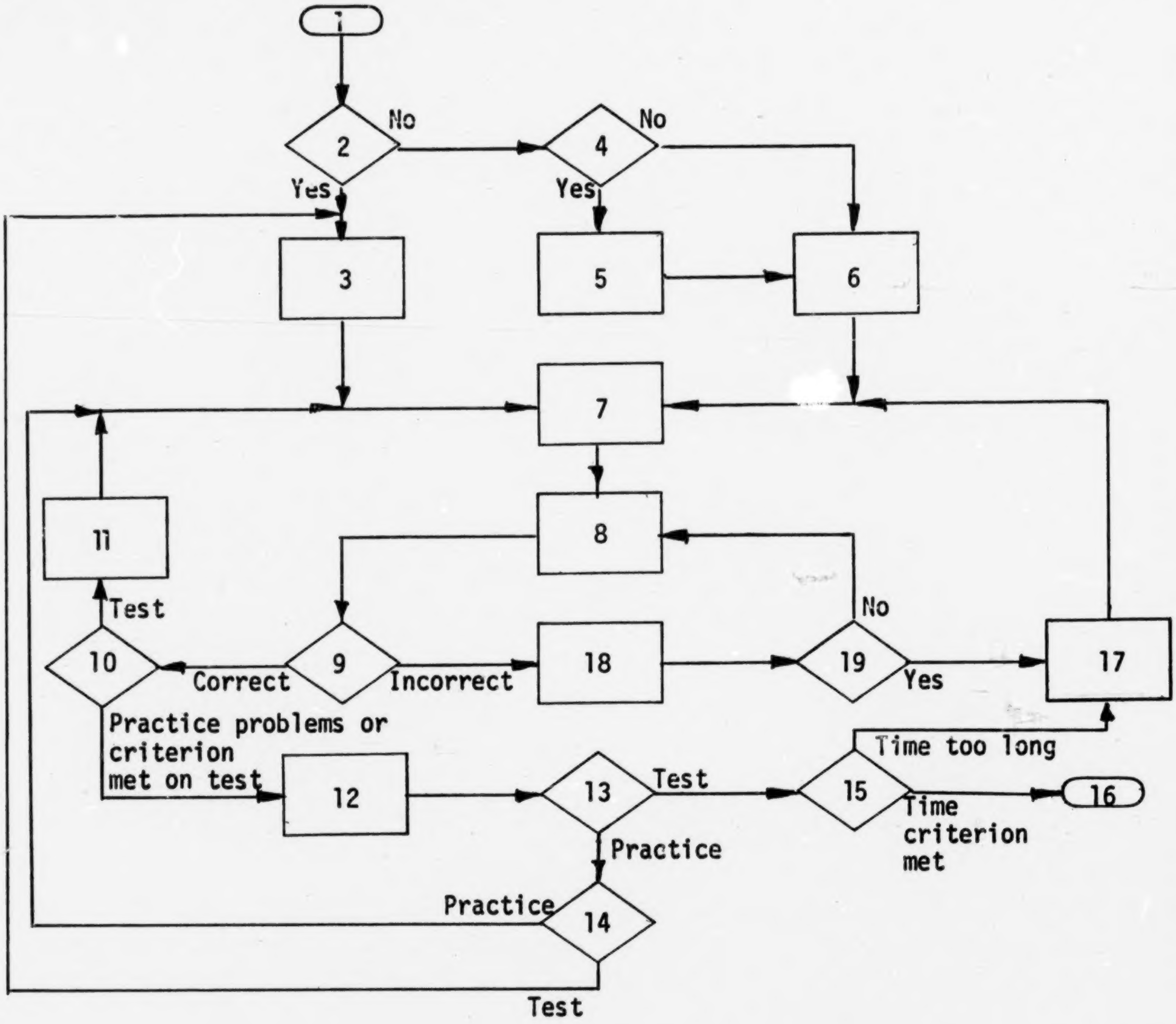

1
2
No
Yes
4
No
Yes
3
5
6
7
8
11
Test
10
9
Correct
Incorrect
18
19
No
Yes
17
Practice problems or criterion met on test
12
13
Test
15
Time too long
16
Time criterion met
Practice
14
Practice
Test

Fig. 12. Student choice of additional practice or test.

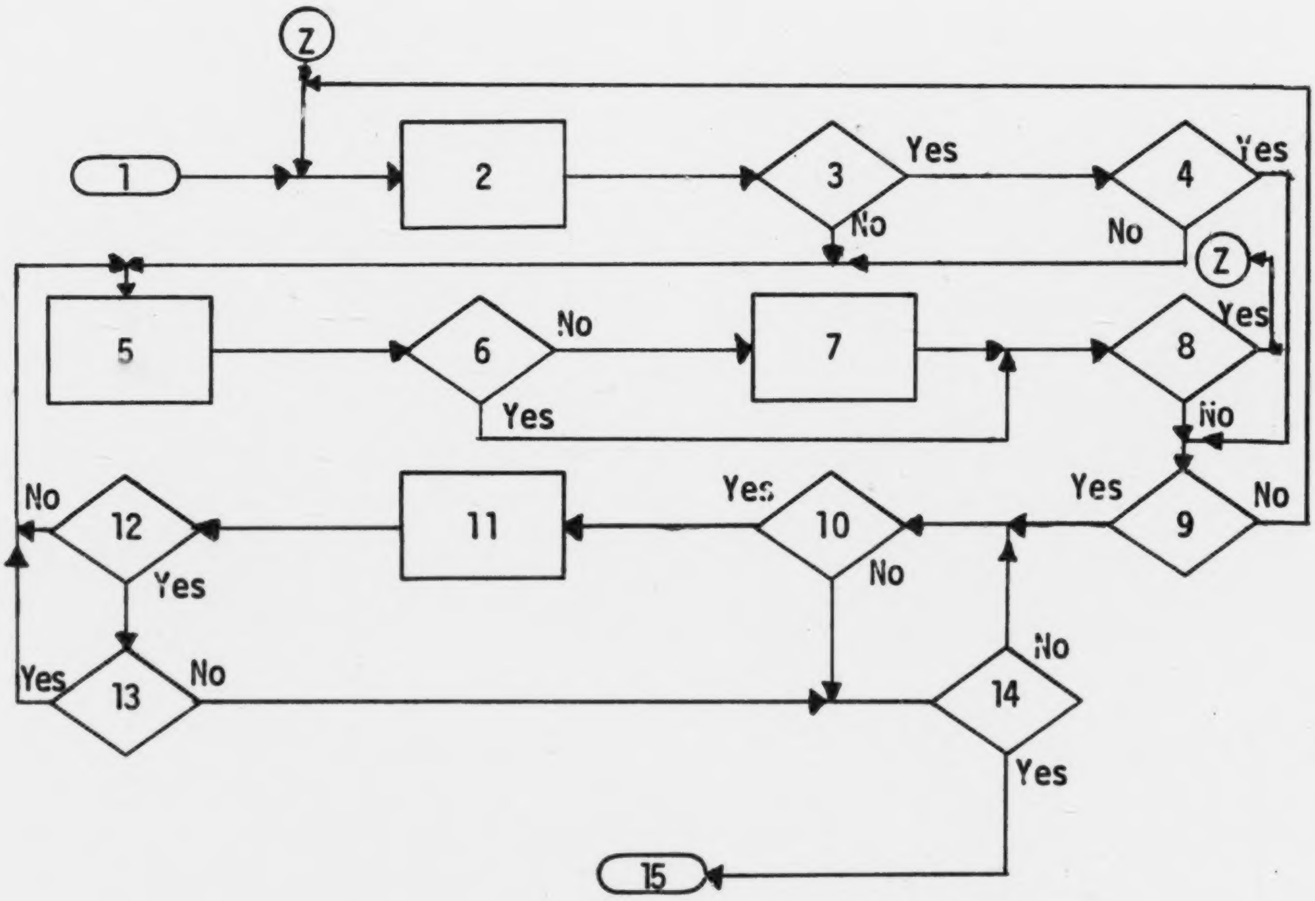
Key to Flowchart - Student Given Option to Skip Sections of Course[3]

1. Begin
2. Preview of section n, including a content outline
3. Is the student following a flexible sequence? (This can be determined by a pretest, by the instructor, or by previous work in the course.)
4. "Do you want to skip this section?"
5. Presentation to section n material
6. Did the student know the material well enough to proceed?
7. Remedial instruction given on section n
8. Student is allowed to decide whether or not he will receive a repeat presentation of the material in the section just covered; option is given even if student achieved criterion
9. Has the student been through the entire course prior to this?
10. "Did the student skip section n?" Beginning with the first section, a check is made to determine which sections were skipped
11. Test on section n
12. Did the student do well enough on the test?
13. "Do you want to study section n?" Option is given even though criterion was met
14. Has student completed or been tested on all sections?
15. End

---

[3] From Penn State's course segment Audiology, Project No. 5-1194, IBM 7010 or 1410; authors: Bruce M. Siegenthaler, Jeffrey Katzer.

Student Given Option to Skip Sections of Course


Z
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Yes
No
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Yes
No
Z
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6
No
Yes
7
8
Yes
No
9
Yes
No
10
Yes
No
11
12
No
Yes
13
Yes
No
14
No
Yes
15

Fig. 13. Student given option to skip sections of course.

Key to Flowchart - Type of Sequence Through Course Chosen by Student[4]

1. Start
2. Introduction
3. Choice of programed sequence (A), self-structured sequence (B), or quiz (C)
4. Instruction on concept n
5. Branch depending on choice made in step 3; for the regular programed sequence, steps 4 and 5 are repeated as many times as the number of concepts to be presented, each time a new concept being presented.
6. Have all concepts been presented?
7. Choice of instruction on any of the concepts or the quiz on these concepts
8. Quiz on concept n; for regular programed sequence, quiz includes all concepts
9. Branch depending on choice made in step 3 (A, B, or c)
10. Score on most recent questions revealed to students and opportunity to review specified concepts given and carried out
11. Branch depending on choice made in step 3 (B or C)
12. Branch depending on total quiz score
13. Student told that all answers were correct
14. Branch depending on choice made in step 3 (A, B, or C)
15. Statement made to student concerning completion of instruction
16. End
17. Branch made depending on choice made in step 3 (A. B. or C)
18. Student is told on which concepts he is competent and those on which he needs instruction
19. Choice of going to end or back to point where choices can be made of the concepts on which to receive instruction
20. Explanation given on each response which was incorrect
21. Branch depending on choice made in step 3 (A or B)
22. Student can select from all quiz questions and receive explanations regarding them
23. Student can choose whether to go to end or to be given opportunity to review

---

[4] From Penn State's course segment Educational Measurement, Project No. 5-85-074, IBM 7010 or 1410; authors: Keith A. Hall and Harold E. Mitzel.

Type of Sequence Through Course Chosen by Student

A. Regular Programmed Sequence
B. Self-Structured Sequence
C. Quiz

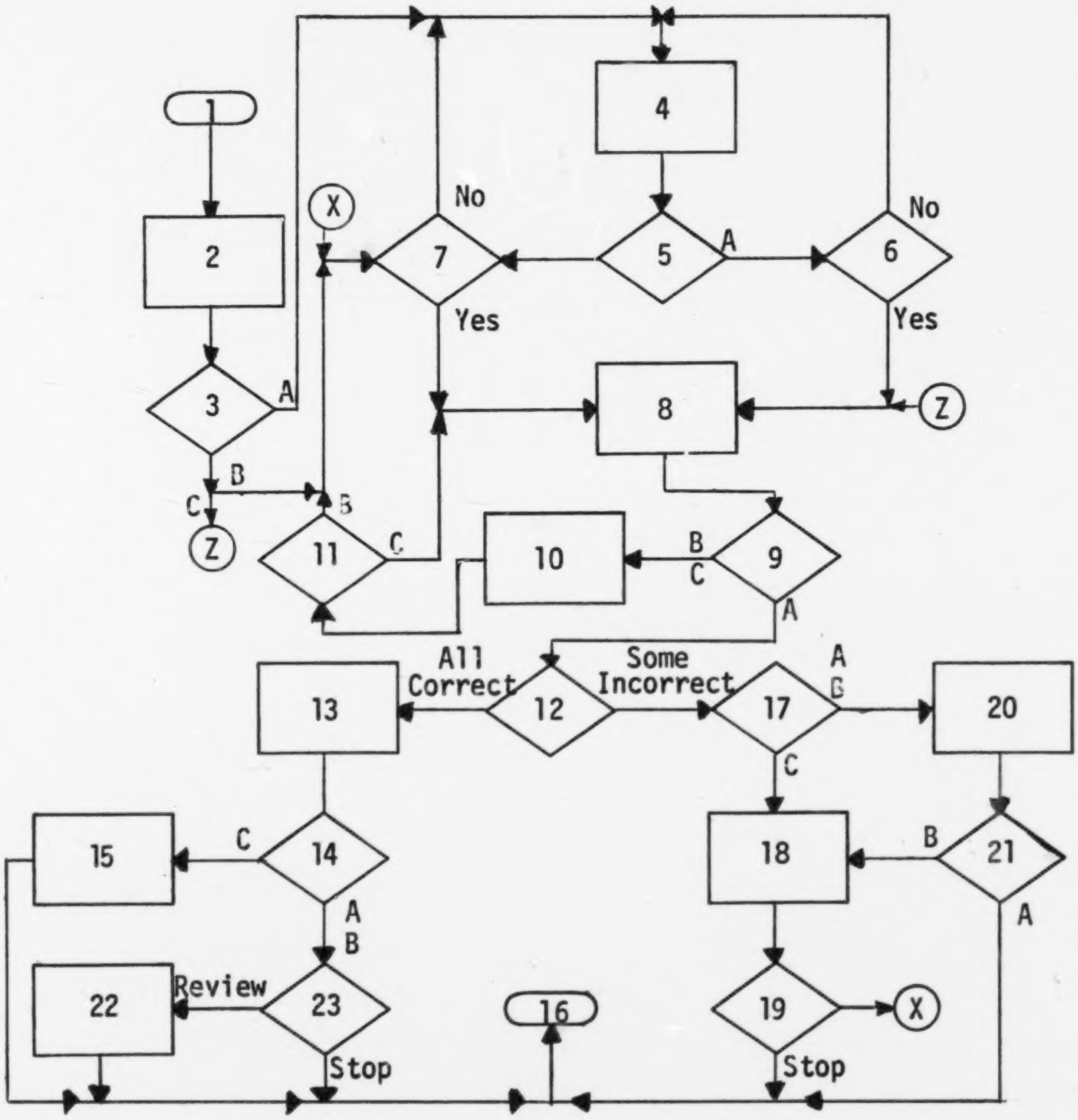

1
2
3
A
B
C
Z
4
5
A
6
No
Yes
Z
7
No
Yes
X
8
9
B
C
A
10
11
B
C
12
All Correct
Some Incorrect
13
14
C
A
B
15
16
17
A
B
C
18
19
Stop
X
20
21
B
A
22
23
Review
Stop

Fig. 14. Type of sequence through course chosen by student.

Student-control of course content. A "map" of the entire course is shown to the student at the beginning of the course. The map would consist of interrelated blocks containing the topics included in the course. The student may select any segment of this map for further scrutiny. At this point he is given a more close-up view of the segment that he selected. He can continue this process of going deeper and deeper into the course material or into the maps, or he can indicate that he wants to withdraw one step or move sideways to another map region at the same level in which he is working. At any time, the student may go back to the main map (see Figure 15).

Student choice to receive explanation of quiz questions and/or review. Student receives introduction, then instruction; he then has a choice of reviewing the instruction, stopping until a later time, or continuing with more instruction followed by a two-part quiz. At the end of part 1 of the quiz the student has the option of receiving an explanation of any or all of the questions. After receiving the explanations or deciding not to receive them, he proceeds to the second part of the quiz. His score is given at the end of the entire quiz. He then has the option of going on to the next chapter, repeating this chapter, or stopping (see Figure 16).

Student-adapted multi-level instruction. A course can be comprised of several independent blocks of instruction. Strategy may allow the student to select the order he will enter the blocks of instruction. When a block is entered, the student first receives a diagnostic test on the content of the block; if performance is satisfactory, the block is exited; otherwise, the student will receive instruction followed by a criterion test. If criterion is not met, the student can choose his next block of instruction. Within each block, the student may elect to enter review and request help routines (see Figure 17).

Section Flowcharts

The strategies presented here represent sections of a course. Many include programing over several questions or frames, such as those giving cumulative feedback relative to a set of questions.

Key to Flowchart - Student-Control of Course Content

1. Start
2. Main map of the course is shown to student; (sections on the main map could be descriptive chapter titles)
3. Did the student choose to explore section 1 further?
4. Sections 2, 3, and so on, all of which have flow similar to section 1
5. Map indicating subsections of section 1 is shown to the student; (this map could be chapter subtitles)
6. Was "main map" chosen?
7. Was a related section at the same level selected?
8. Was subsection 1 chosen by the student?
9. Subsections 2, 3, etc., of section 1; each is similar in flow to subsection 1
10. Items for study within subsection 1 are shown in map form to the student
11. Was "main map" chosen?
12. Was a related subsection at the same level selected?
13. Was the subsection map for section 1 selected?
14. Was item 1 of the map selected?
15. Items 2, 3, and so on of subsection 1; the flow in each is similar to that of item 1
16. Instruction on item 1; (within each phase of instruction, the student is allowed to select different topics for study by choosing other parts of the course map)
17. Did the student choose to go back to the "main map?"
18. Did the student select related instruction in subsection 1?
19. Did the student select the subsection map for section 1?
20. Did the student select the item map in subsection 1?
21. Continuation of instruction on item 1

Student-Control of Course Content

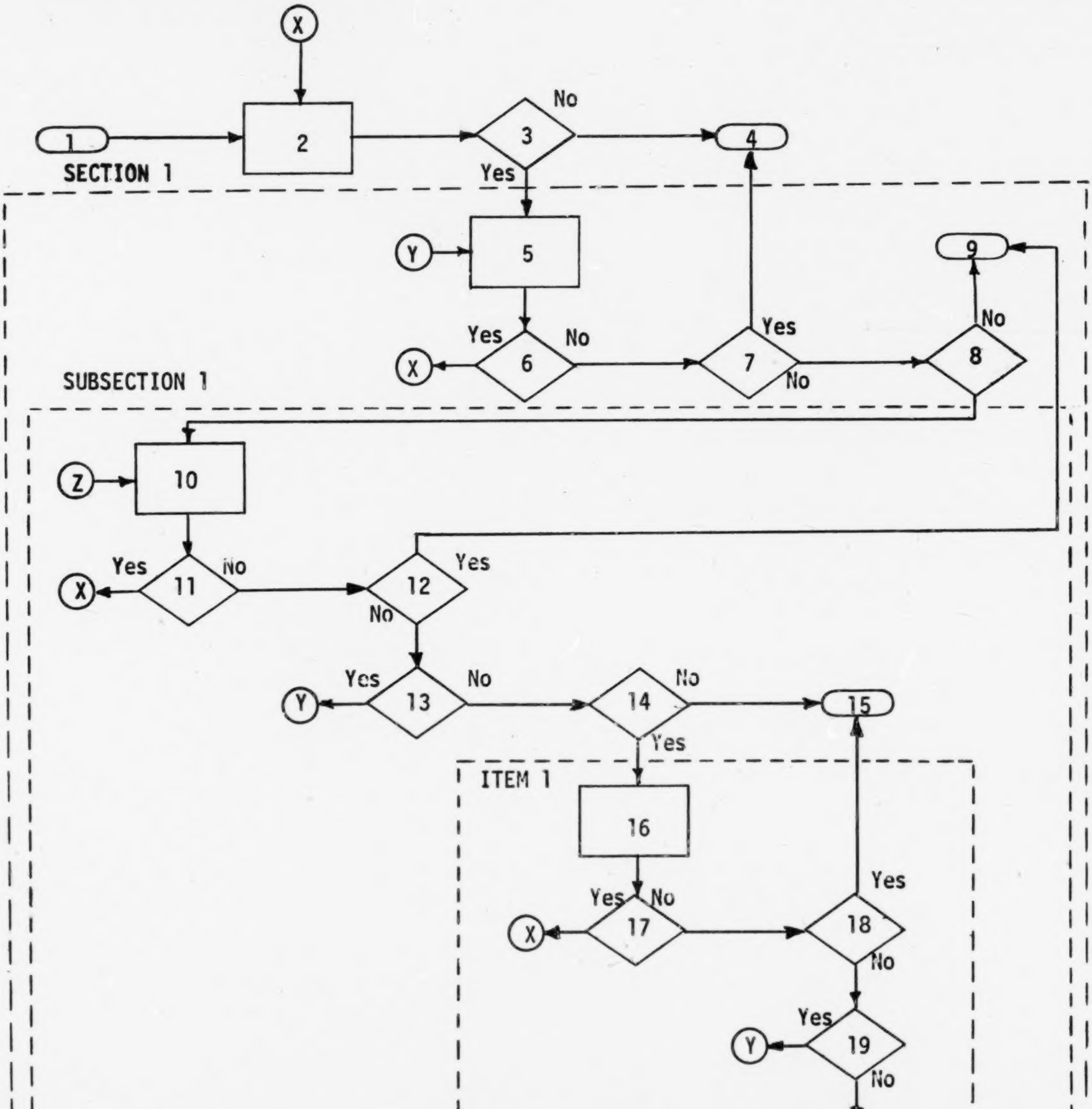

X
1
2
3
No
4
SECTION 1
Yes
Y
5
9
Yes
6
No
7
Yes
No
8
No
X
SUBSECTION 1
Z
10
Yes
11
No
12
Yes
No
X
Yes
13
No
14
No
15
Y
Yes
ITEM 1
16
Yes
No
17
18
Yes
X
No
Yes
19
Y
No
Yes
20
Z
No
21

Fig. 15. Student-control of course content.

Key to Flowchart

Student Choice to Receive Explanation of Quiz Questions and/or Review[5]

1. Start
2. Introduction to the course segment
3. Beginning of instruction
4. Student is given option to receive either a review of previous instruction, or instruction on new material
5. Review of previous instruction
6. Instruction presented on new material
7. Part 1 of quiz
8. "Do you want an explanation of question 1 in part 1 or quiz, or all questions explained?"
9. Explanation of question n
10. Has option for all questions been given?
11. Do you want an explanation of next question?
12. Explanation of each question in Part 1 of quiz
13. Part 2 of quiz
14. Feedback is given: "Your score for Part 1 and 2 of quiz is _____."
15. Student is given option to proceed to the next section; repeat this section; or stop
16. Next section
17. Stop

---

[5] From Penn State's course segment Management Accounting, Project No. 5-1194, IBM 7010 or 1410; authors: Joe J. Cramer and Carl R. Palmer.

Student Choice to Receive Explanation of Quiz Questions and/or Review

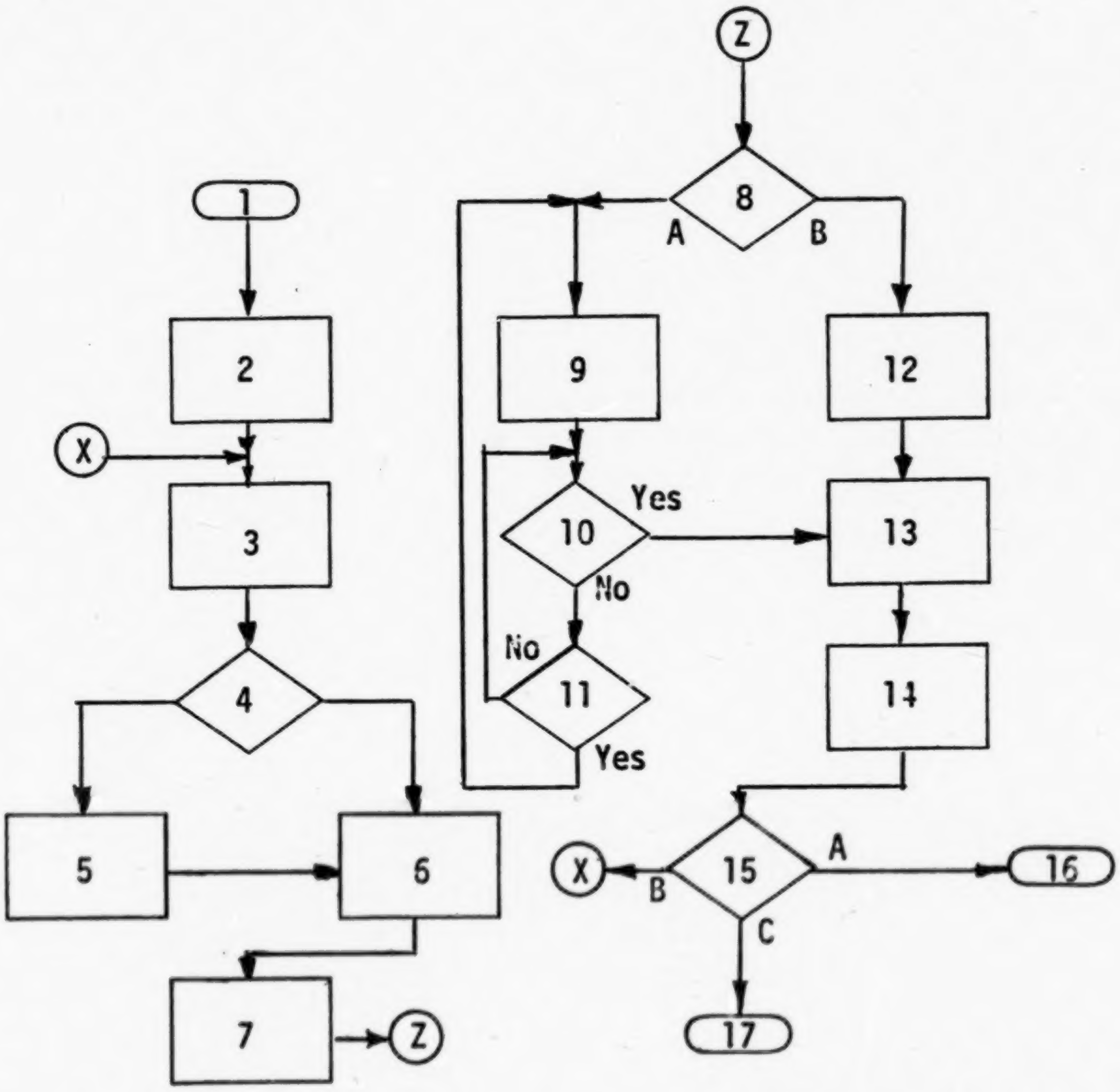

Z
8
A
B
1
2
9
12
X
Yes
10
13
No
No
11
14
Yes
4
A
5
6
X
B
15
16
C
7
Z
17

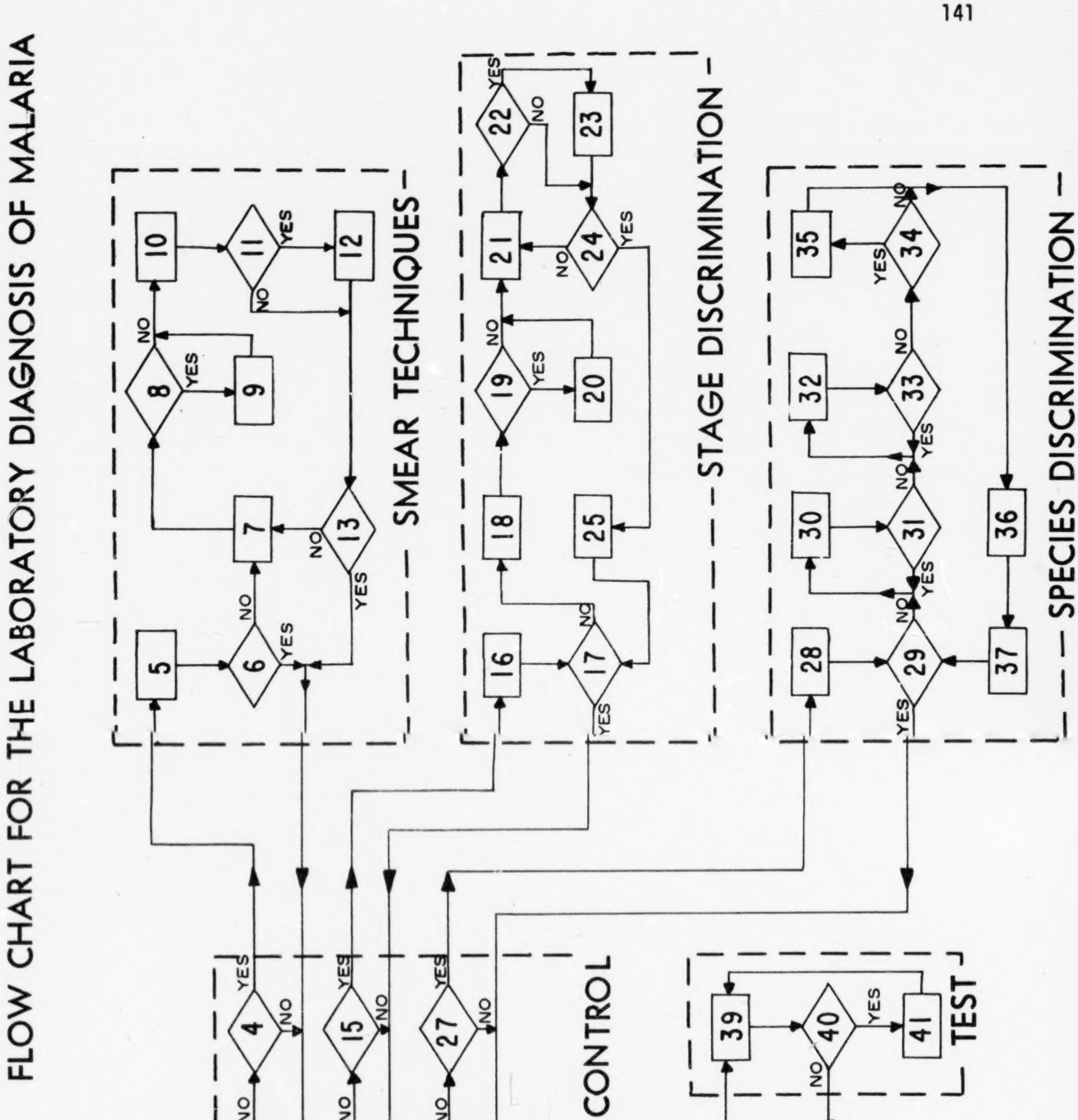
Fig. 16. Student choice to receive explanation of quiz questions and/or review.

Key to Flowchart - Student-Adapted Multi-Level Instruction[6]

1. Sign on
2. Introduction to course: list of topic areas
3. Has student completed smear technique?
4. Did student elect to enter smear technique?
5. Diagnostic test: smear technique
6. Was student performance satisfactory?
7. Instruction: smear technique
8. Does the student wish to review?
9. Review: blood smear technique
10. Criterion test: smear technique
11. Is remedial work required?
12. Remedial: smear technique
13. Has criterion been reached?
14. Has student completed stage instruction?
15. Did student elect to enter stage instruction?
16. Diagnostic test: stage instruction
17. Was student performance satisfactory?
18. Instruction: stage discrimination
19. Does the student wish to review?
20. Review: stage discrimination
21. Stage drill
22. Has student requested assistance?
23. Assistance: stage drill
24. Has student completed the drill
25. Criterion test: stage discrimination
26. Has student completed species diagnosis?
27. Does student wish to enter species diagnosis?
28. Diagnostic test: species diagnosis
29. Was student performance satisfactory?
30. Instruction: diagnostic properties
31. Is further instruction required?
32. Instruction: artifact discrimination
33. Is further instruction required?
34. Does the student wish to review?
35. Review: species diagnosis
36. Species drill
37. Criterion test: species diagnosis
38. Has student completed all sections?
39. Off-line microscope test
40. Is remedial work required?
41. Remedial: species diagnosis
42. Sign off

---

[6] From Penn State's course segment Laboratory Diagnosis of Malaria, Office of Naval Research, Contract No. N00014-67-A-0385-0003, IBM 7010 or 1410; authors: CDR M. Stirewalt Lincicome, MSC, USN; Richard Beaudoin; HMC Dean Armstrong, USN (Ret.); HM1 Arthur Wentland, USN; Leslye Bloom.


FLOW CHART FOR THE LABORATORY DIAGNOSIS OF MALARIA
SMEAR TECHNIQUES
STAGE DISCRIMINATION
SPECIES DISCRIMINATION
CONTROL
TEST
1
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5
6
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8
9
10
11
12
13
14
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24
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28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
YES
NO

Fig. 17. Student-adapted multi-level instruction.

Giving Cumulative Feedback

One of the primary advantages of computer-assisted instruction is the facility each student is given by providing feedback concerning his progress. After information is accumulated about the student's performance, problems can be assigned to additional instruction or drill.

Indicating response latency to student. Each time the student answers a question, his response latency is added to a counter. When his answer is processed, he is told whether he is right or wrong and how many seconds he spent on the question (see Figure 18).

Testing student and giving feedback to student and proctor. This routine is designed for a test situation. The test is written in a manner that will present ten problems one at a time with the answers and problems remaining visible. When the student completes the last problem, the program analyzes all answers and indicates to the student whether each answer is correct (see Figure 19).

Giving information to proctor when student completes an instructional session. When a student has completed an instructional session, it may be desirable to have information on his performance: what part of the course he completed; how many questions he answered in session; how many questions he answered correctly on first attempt; how many times did the student time-out; and how many minutes was the student on the course (see Figure 20).

Flexible Course Flow

One of the difficulties with conventional classroom teaching is that the instruction cannot be made suitable for a wide range of capabilities and interests. CAI courses can be programed to allow for individual differences and difficulties.

Student control of course flow. In the initial development of a course the author cannot be certain that the selected content and organization of the course is the most efficient for achievement of the objectives of the course. Even after revisions are made on the basis of student performance and observations by the students, instructor, and others, a program which does not allow for individual differences may not achieve the objectives efficiently.

Key to Flowchart - Indicating Response Latency to Student[7]

1. Start
2. Initialize to zero counter used to accumulate response latency (counter n)
3. Update restart record so that if student signs off before the problem is completed correctly, this will be the restart point
4. Show the proper image on the image projector
5. Display the statement: Examine the image. What is the atomic number of sodium?
6. Student may respond to the question
7. Add response latency to counter n
8. Is answer correct? If so, go to 9, if not, go to 10
9. Display contents of counter n within the statement: It took you ___ seconds to answer the question correctly
10. Display counter n within the statements: Wrong. You have now spent ___ seconds trying to answer this question
11. Next problem

---

[7] From Penn State's course segment Atomic Energy, Project No. 5-85-074, IBM 7010 or 1410; author: David A. Gilman.

Indicating Response Latency to Student

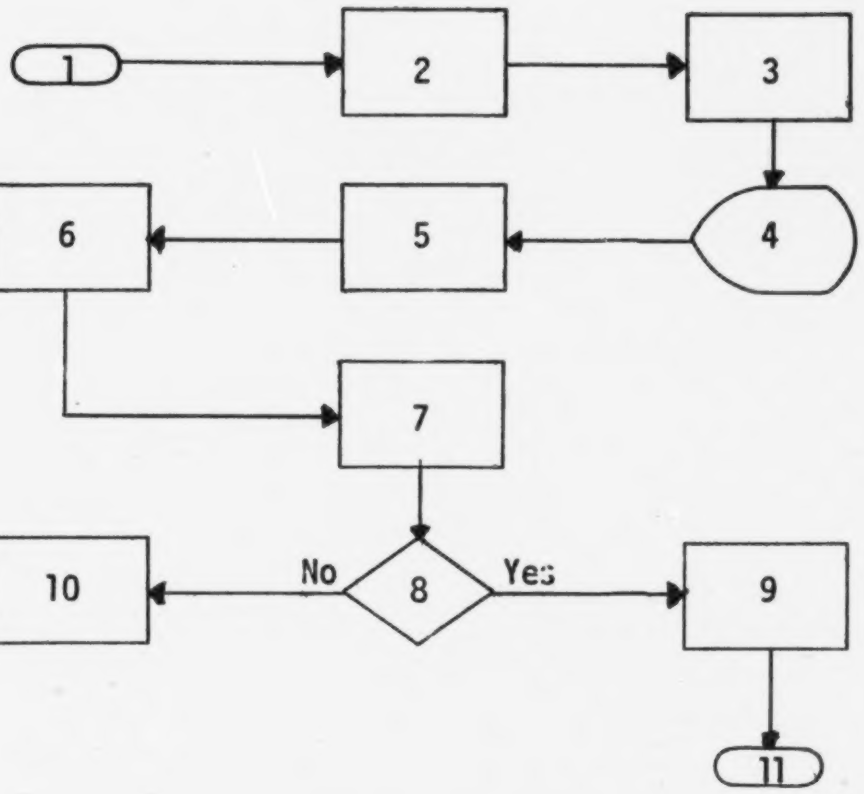

1
2
3
4
5
6
7
8
No
Yes
9
10
11

Fig. 18. Indicating response latency to student.

Key to Flowchart - Testing Student and Giving Feedback to Student and Proctor

1. Start
2. Display example problem on the image projector
3. Display one problem and allow student to respond
4. Is student's response correct? If so, go to 6; otherwise go to 5
5. Load 0 into appropriate switch
6. Load 1 into appropriate switch
7. Move the problem label (A, B, etc.) into a buffer area for later use to display to proctor which problems were correct
8. Add 1 to total-correct counter
9. Are all the test problems displayed? If not go to 3; otherwise go to 10
10. Test the switch recording correctness of each problem. If equal to zero, go to 11; otherwise go to 12
11. Indicate a wrong answer by placing the letter 'w' beside the appropriate problem label and go to 13
12. Indicate a correct answer by placing the letter 'r' beside the appropriate problem label and go to 13
13. Have all switches been tested? If so, go to 14; otherwise go to 10
14. Send proctor message; that is, display contents of appropriate buffers, counters, and switches at proctor station
15. End of test

Testing Student and Giving Feedback to Student and Proctor

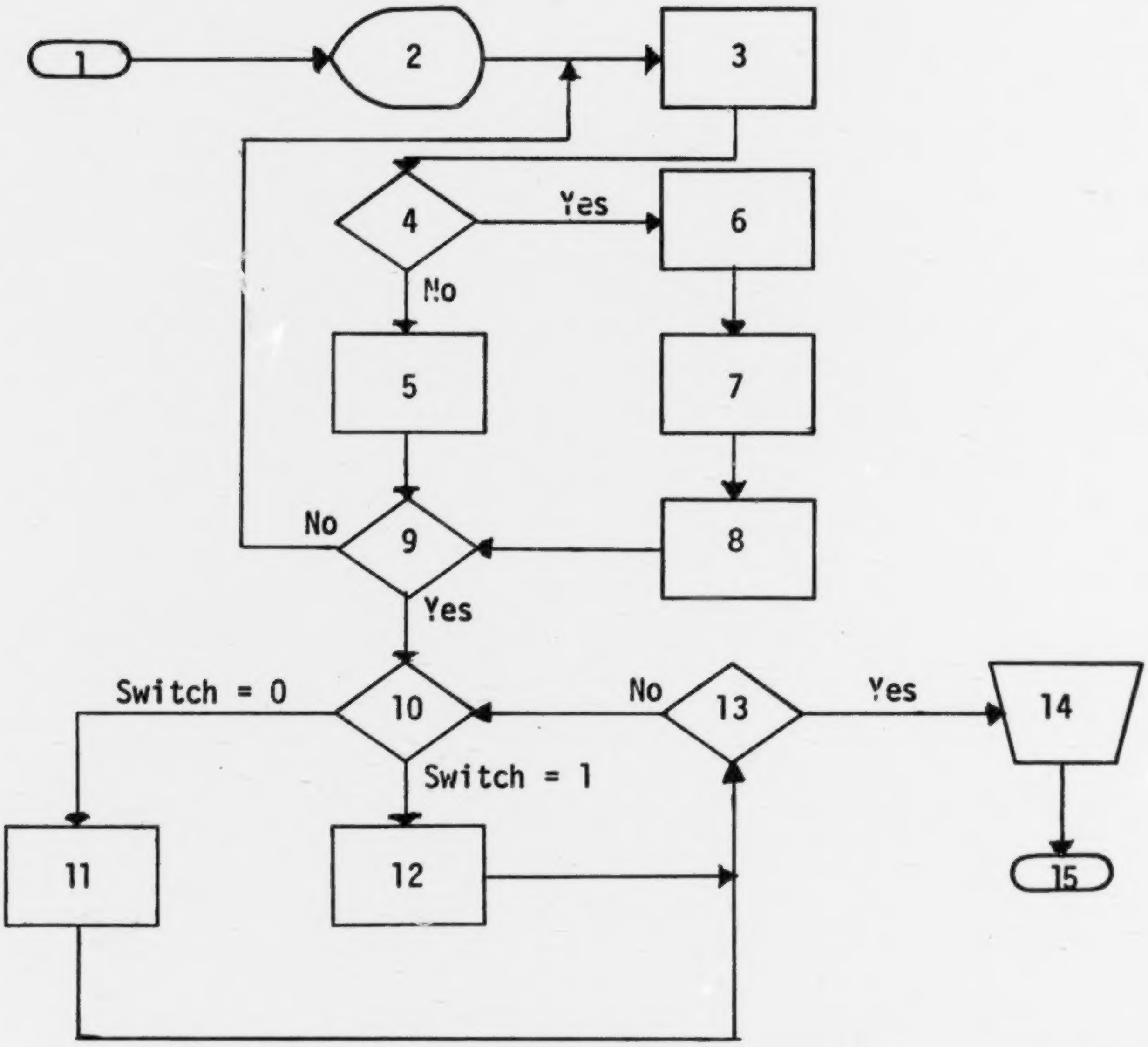

1
2
3
4
Yes
6
No
5
7
No
9
8
Yes
Switch = 0
10
No
13
Yes
14
Switch = 1
11
12
15

Fig. 19. Testing student and giving feedback to student and proctor.

Key to Flowchart

Giving Information to Proctor when Student Completes an Instructional Session[8]

1. Sign on
2. Initialization of counters to be used for recording of number of questions answered, number answered correctly on the first attempt, number of time-outs, etc.
3. Body of instruction which uses the specified counters to record information
4. Question is presented and student has chance to respond
5. Did student indicate that he wants to sign off instead of responding to question?
6. Sending of messages to proctor consisting of information on the student's performance during the recent session
7. End of session; when student signs on again he will be restarted at beginning of the section in which he signed off
8. Analysis of response and continuation of instruction

---

[8] From Penn State's course segments Algebra and General Math, U. S. Office of Education through the School District of Pittsburgh, prime contract Grant No. OEG-0-8-055230-3479, Project No. 5523, IBM 1500 system; authors: Carol Dwyer, Robert Igo, Terry Bahn, Diana Ryall.

Giving Information to Proctor when Student Completes an Instructional Session

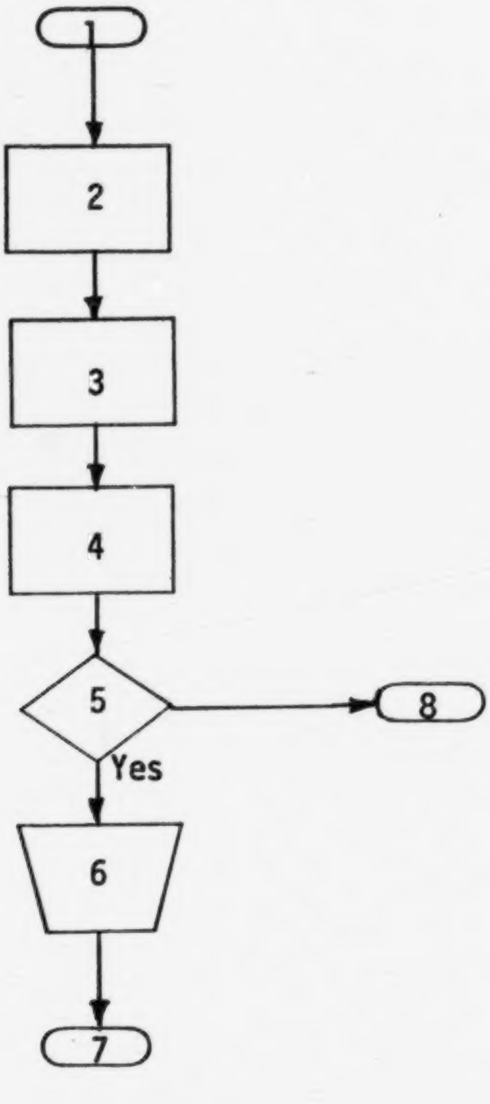


Fig. 20. Giving information to proctor when student completes an instructional session.

If while remaining in the basic framework planned by the author, the student can control course flow, performance of the student may be improved; and, in addition, when the instructor reviews the flow through the course selected by the student, he may receive clues as to where revisions are needed. Computer-assisted instruction can provide great opportunity for student-control of course flow. At each question, prior to answer analysis, tests may be made for a special code which, if typed by the student, indicates a request for one of the options available in the course that will alter course flow (see Figure 21).

Sequence based on number of consecutive problems which are correct. A student who has mastered a concept will lose interest if he is required to answer question after question using this concept. In a set of practice exercises, flexibility can result by having many exercises available and branching out of the sequence of exercises if the student answers correctly a specific number of consecutive problems (see Figure 22).

Allowing student to change responses. The student is given four problems to solve. He answers each one individually in order with his answer being placed next to the corresponding question. After the responses have been given, but before feedback as to correctness is made, the student is given the option to change any of his answers. After any desired changes are made, analysis is done and feedback is given on all problems (see Figure 23).

Question-Level Flowcharts

Question-level flowcharts involve the strategy required for a single question, problem, or frame. The strategies presented here are merely a representative sample of possible sequences at the question or frame level.

Individualization of Presentation

One criticism of computer-assisted instruction is that receiving instruction via a machine is too impersonal. However, there are means by which an author can decrease the feeling of the student that he is alone with a powerful mechanical device.

Key to Flowchart - Student Control of Course Flow

1. Start of lesson
2. Series of problems
3. Problem immediately preceding the current problem
4. Preliminary instructions for the current problem are presented
5. The problem is presented
6. Student may respond to the question
7. Was an unavailable option requested?
8. Message that the selected option is not available at this time
9. Was a request for help from the proctor made by the student? that is, did the student type "-h"?
10. Proctor message is sent to the proctor station and the student is told to wait for assistance
11. Did the student request a review of the lesson? that is, did the student type "-r"?
12. Review questions and discussion of the material covered thus far in the current lesson and pertinent information from previous lessons
13. Did the student request a summary of the current lesson? that is, did the student type "-s"?
14. Presentation of summary statements of information presented in the current lesson
15. Did the student request to go back to the beginning of the current problem? that is, did the student type "-p"?
16. Did the student request to go back to the previous problem? that is, did the student type "-b"?
17. Did the student request to go back to the beginning of the current lesson? that is, did the student type "-l"?
18. Did the student request to go to the end of the current lesson? that is, did the student type "-e"?
19. Did the student request to go to the next problem in sequence? that is, did the student type "-n"?
20. Did the student type the correct answer to the question?
21. Feedback for correct response
22. Next problem in sequence
23. Additional answer analysis instructions
24. End of the current lesson

Student Control of Course Flow

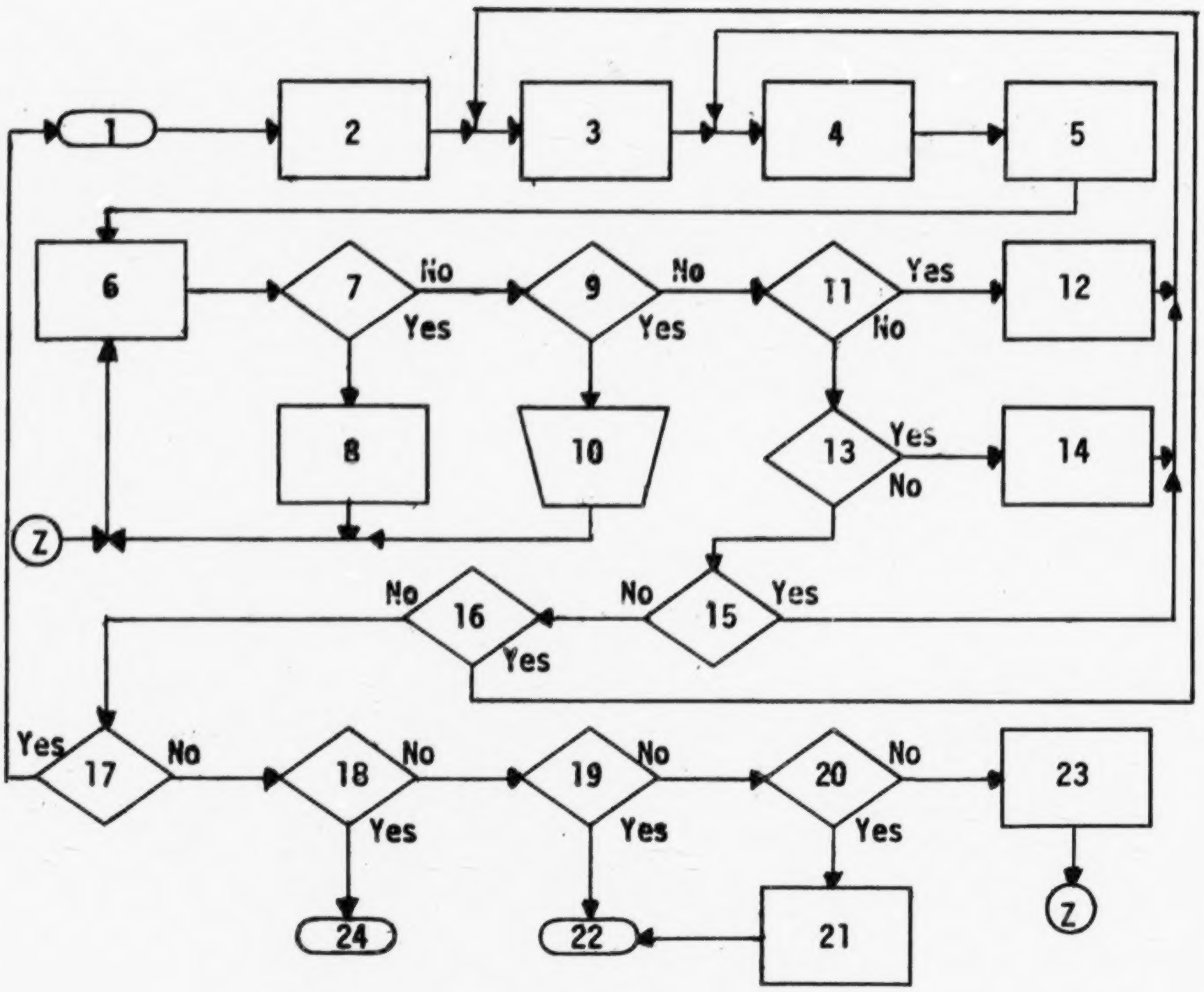

1
2
3
4
5
6
7
No
Yes
8
9
No
Yes
10
11
Yes
No
12
13
Yes
No
14
Z
15
No
Yes
16
No
Yes
17
Yes
No
18
No
Yes
19
No
Yes
20
No
Yes
21
22
23
24
Z

Fig. 21. Student control of course flow.

Key to Flowchart

Sequence Based on Number of Consecutive Problems which are Correct

1. Start
2. Initialize specific counters for scorekeeping and give instructions
3. Question is presented and student responds
4. Is the answer correct? If yes, go to 5; if not, go to 12
5. Give feedback that response is correct; add 1 to the total-correct counter; add 1 to the counter storing the number of consecutive correct problems
6. Has criterion of getting a certain number of consecutive problems correct been met? If yes, go to 7; otherwise, go to 8
7. Indicate that criterion has been met and go on to next section
8. Have all learning exercises been presented?
9. Did the student have 60% of all problems correct?
10. Present several practice problems with specific feedback when incorrect
11. Give intensive remedial instruction and practice exercises
12. Indicate to the student that response is incorrect and give specific feedback to assist the student in understanding how to correctly answer the problem
13. Initialize to zero the counter in which the number of consecutive correct problems is stored

Sequence Based on Number of Consecutive Problems which are Correct

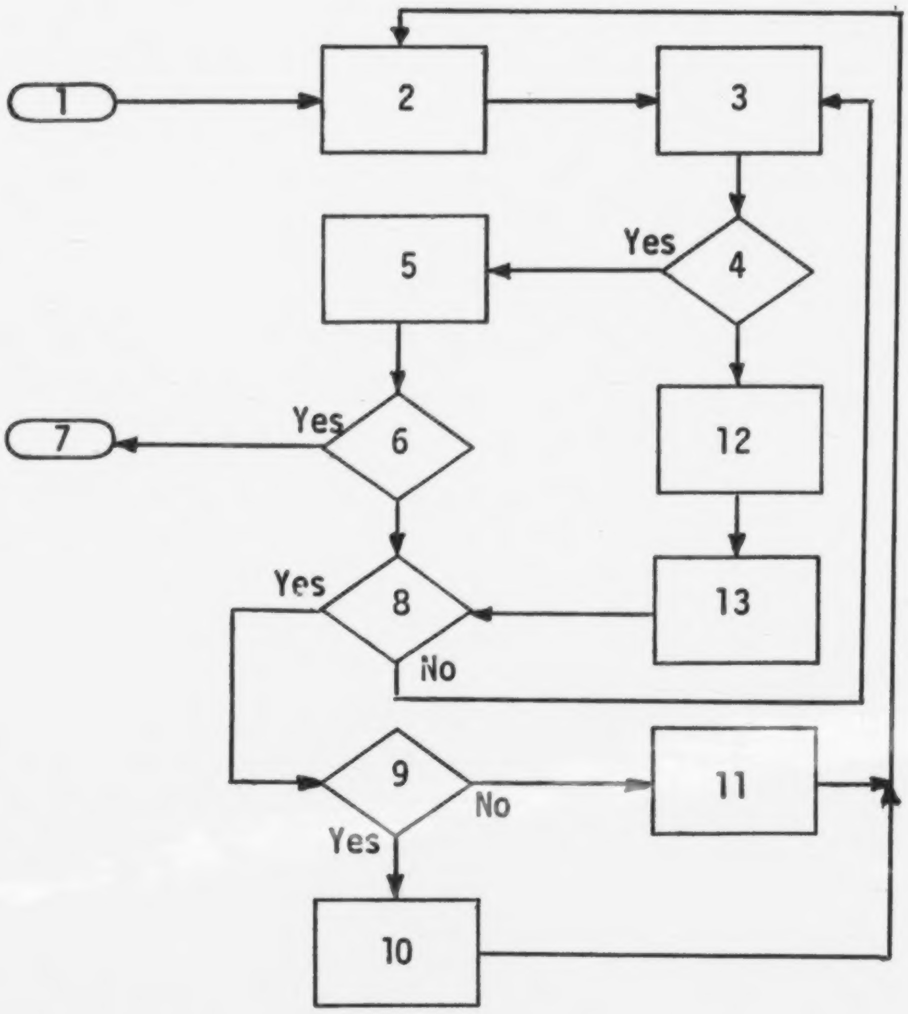

1
2
3
Yes
4
5
Yes
6
7
12
Yes
8
13
No
9
No
11
Yes
10

Fig. 22. Sequence based on number of consecutive problems which are correct.

Key to Flowchart - Allowing Student to Change Responses[9]

1. Four problems are presented
2. Student is allowed to respond to one of the questions; response is placed below the question
3. The response and whether it is correct is recorded
4. Have all questions been answered? If so, go to 5; if not go to 2
5. Student is asked whether or not he would like to change any answers; if so, go to 6, if not, go to 10
6. Student is given the opportunity to list the numbers of the problems he would like to change
7. Has the student been given the opportunity to change all problems that he wanted to change? If yes, go to 10; if no go to 8
8. Has student indicated that he would like to change problem n? If yes, go to 9; if no go to 7
9. Student responds again to problem n; his answer and whether or not it is correct is recorded in place of the former results
10. Student is told which answers are correct and which are incorrect
11. Next problem

---

[9] From Penn State's course segment Algebra, U. S. Office of Education through the School District of Pittsburgh, prime contract Grant No. OEG-0-8-055230-3479, Project No. 5523, IBM 1500 system; authors: Catherine Folger and John McNear.

Allowing Student to Change Responses

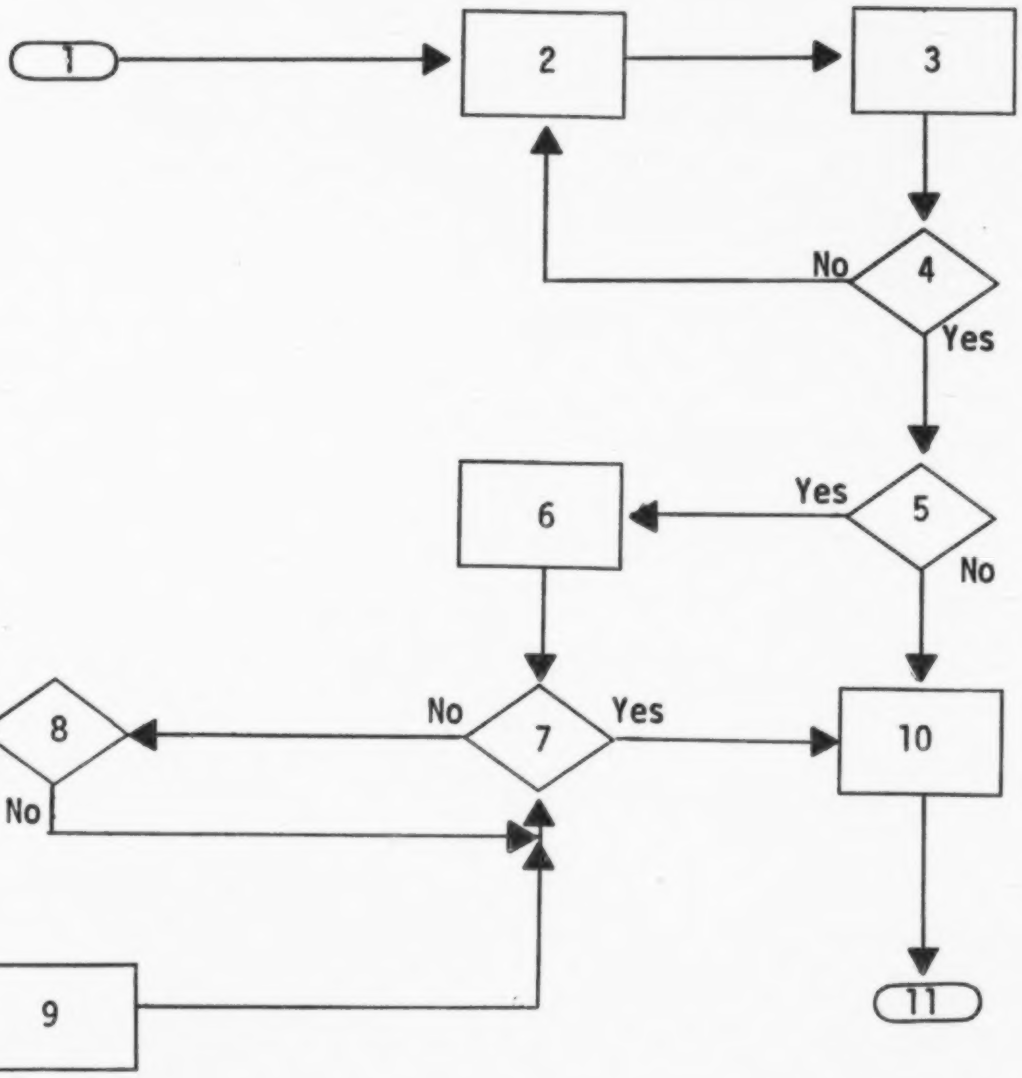

1
2
3
4
No
Yes
5
Yes
No
6
7
No
Yes
8
Yes
No
9
10
11

Fig. 23. Allowing student to change responses.

Introduction of new concept. Assume that a new concept is to be introduced. Since the purpose of the question to be asked is to provide a provocative introduction or bridge to what comes next, the student's response should not be checked for correctness. However, when the student has completed his response, he is presented with some correct answers before continuing.

Flow proceeds directly in order:

1. Display question: What is a noun?
2. Student is allowed to respond
3. Feedback is presented to the student that begins, "You should have typed. . ."
4. The student indicates when he is ready to go on

Personalizing a course by using student's name. It is possible to make the student feel that the course has been individualized by using his name in asking questions and in giving him feedback. This can be done easily by asking the student to type his first name at the beginning of the course or by retrieval of the student's name from his record.

Flow proceeds in order:

1. The student is asked a question
2. The student responds
3. Appropriate feedback and the student's name are displayed

Displaying student's response. It may be desirable to display the response made by the student. Any response the student makes is saved until the next response request. Therefore, all that is necessary is for the response to be displayed in an appropriate place.

Procedure could be:

Display the phrase, "You responded" followed by the student's response and the question, "Is this what you meant to say?"

Requests Made by Student

Students participating in computer-assisted instruction are usually accustomed to conventional classroom instruction in which many of their questions are answered and individual problems may be solved with a brief request. With CAI, students may have the option to request individual assistance from a teacher and also to make other requests.

Student may request assistance from proctor. Situations may arise in which the student reaches an impasse in the course. One way this could happen is within a question frame that required the student to give a correct answer before he goes on to the next frame, but the student cannot determine the correct answer from the hints given. The student cannot go on without help, and if the help required is not programed into the course he can enter a request for help from the proctor who could then give him individual assistance (see Figure 24).

Student may request correct answer. The author allows the student to request the correct answer to a question by entering the word "go." Once he has been given the correct answer, he must type it before he can proceed to the next material. If the response "go" is not found, the student's response is compared in the usual manner with anticipated correct and incorrect answers, and feedback is given (see Figure 25).

Student may indicate need for review. The student may be told before beginning a series of questions that if he feels a need for a review, such a request may be made by typing the word "review" at the time of a response request instead of entering a response. One of the anticipated responses for each question would be "review" which, if matched, would be followed by a branch to an appropriate review sequence (see Figure 26).

Flexible Feedback

Since computers have the capability to use information about the student, varied feedback can be stored in the program, and its use can depend on the student's personality, background, or performance.

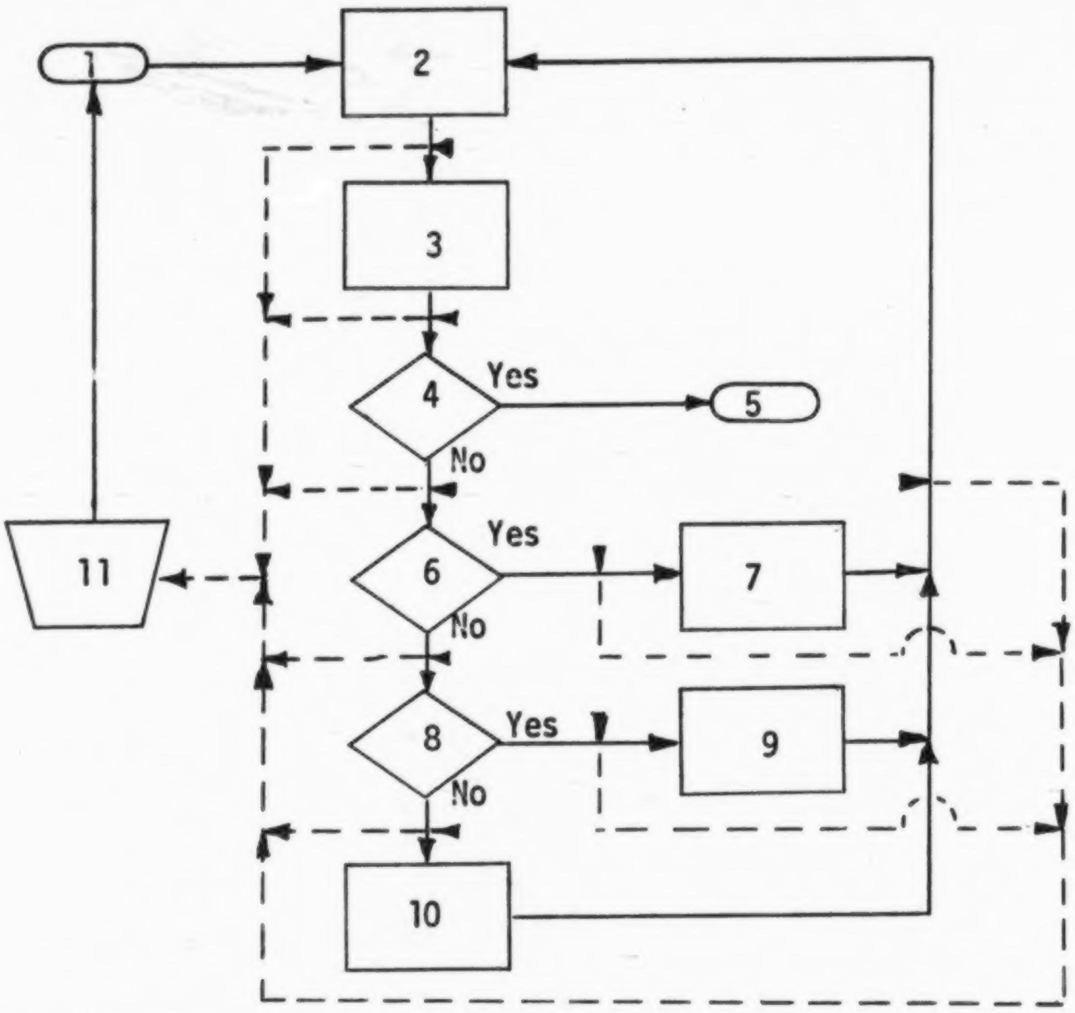
Feedback adjusted to student. Students with many personalities and past achievement and differing in sensitivity and temperament take courses presented by computer-assisted instruction. In a course with one path that all students follow, it is possible to make feedback appropriate to the student. Several types of feedback may be available throughout all of the course or within specific sections such as a review prior to a quiz. As examples, here are three types:

Key to Flowchart - Student May Request Assistance From the Proctor

The student may be given the option to interrupt the flow of the course at any time to request assistance. The dotted lines indicate student-initiated flow.

1. Start of problem
2. Question is presented
3. Student is given opportunity to respond
4. Was answer correct?
5. Appropriate feedback is given and student goes to next problem
6. Was this the first incorrect response?
7. First hint
8. Was this the second incorrect response?
9. Second hint
10. Third hint, which is given on all subsequent responses
11. Proctor message is sent by the student that he needs help; assistance is given by the proctor either on or off line; when the student is ready to continue, the computer automatically branches to the beginning of the current problem

Student May Request Assistance From the Proctor


1
2
3
4
Yes
5
No
6
Yes
7
No
8
Yes
9
No
10
11

Note: Dotted lines indicate points where assistance may be requested.

Fig. 24. Student may request assistance from the proctor.

Key to Flowchart - Student May Request Correct Answer[10]

1. Entry to problem
2. Problem is presented
3. Question is asked
4. Is response "go?"
5. Correct response is given and student is told to type response
6. Additional response analysis takes place
7. Continuation of course

---

[10] From Penn State's course segment Atomic Energy, Project No. 5-85-074, IBM 7010 or 1410; author: David Gilman.

Student May Request Correct Answer

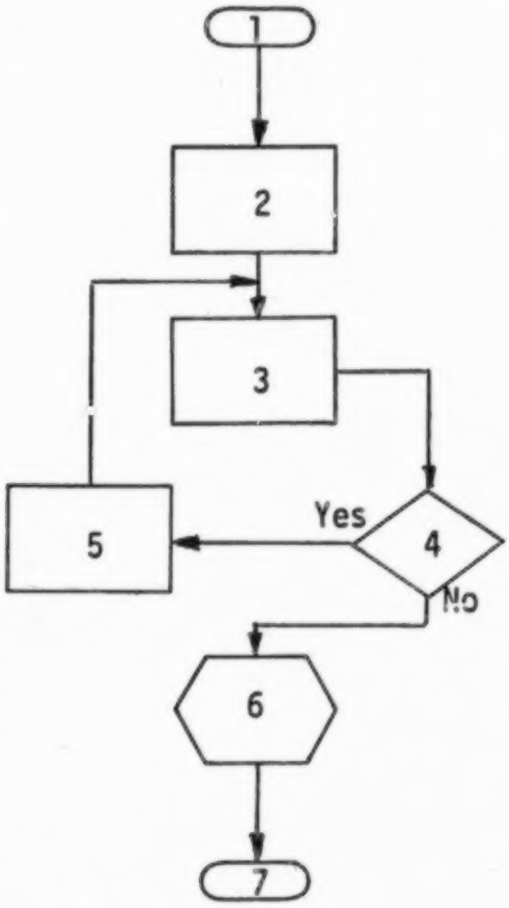

1
2
3
Yes
4
No
5
6
7

Fig. 25. Student may request correct answer

Key to Flowchart - Student May Indicate Need for Review

1. Question is presented
2. Student responds to question
3. Did the student match the correct answer?
4. Did the student match a specific wrong answer?
5. Specific feedback is given
6. Did the student type the word "review"?
7. Review
8. Feedback given for an unrecognized response
9. Feedback for correct response
10. Next problem

Student May Indicate Need for Review

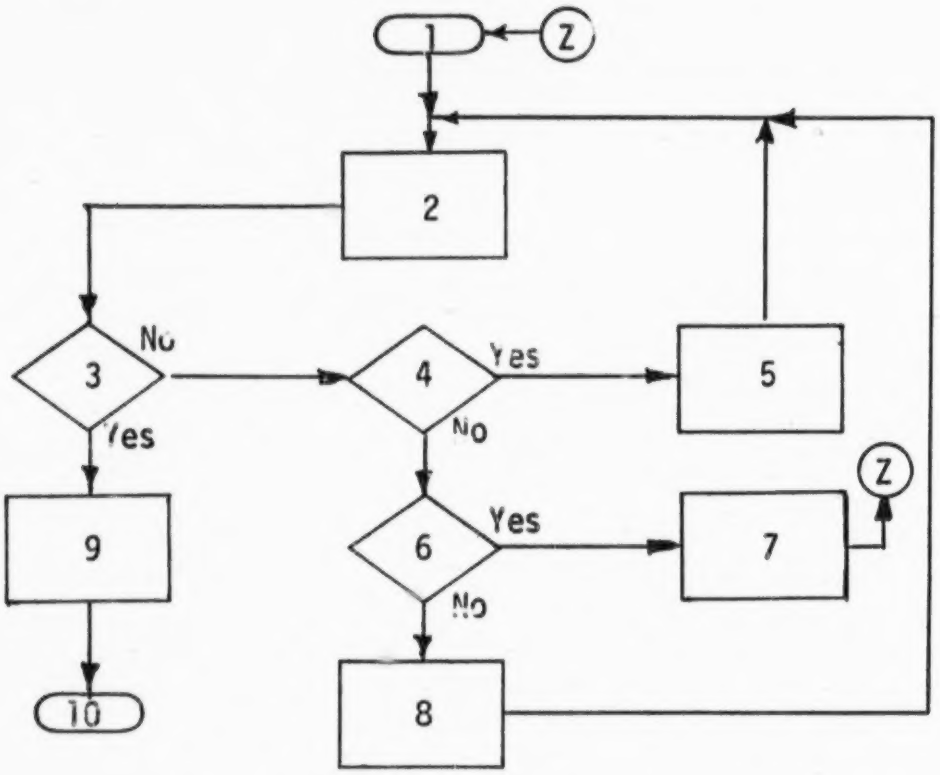

1
Z
2
3
No
Yes
4
Yes
No
5
6
Yes
No
7
Z
9
10
8

Fig. 26. Student may indicate need for review.

1. For the "well-adjusted high-achiever," feedback would be short and could include some information about the gap between the student's ability and his performance.
2. The "non-extreme personality and/or average-achiever" would receive the common type feedback.
3. For the "unconfident low-achiever," feedback would be encouraging and extensive.

When the decision relative to the type of feedback applicable is made, a counter can be loaded with one, two, or three corresponding to the type of feedback. This counter can be checked at the appropriate points in the course to determine which of the three available feedbacks is to be used (see Figure 27).

Varying feedback for each response attempt. Common programing usually provides varying feedback for several anticipated responses. However, many programers do not provide different feedback, for example, if the correct answer is given on the second, third, or fourth attempt as opposed to the first attempt. Feedback of "excellent" on the fourth response to a basic question may make a student lose confidence in the course program. If desirable, it is within the capabilities of CAI to program varying feedback to be used for different response attempts. In the example included here, the flow for a match of the correct answer is shown. The same logic could be followed for each anticipated incorrect response (see Figure 28).

Multiple-level question. "Behind the scenes" in a question from the main flow of a course, there may be a great deal of course material which is not presented to the student who quickly comprehends the objective of the particular lesson; this student answers the question correctly and immediately goes to the next problem in the main flow. However, as in this example, for each of the three incorrect choices in the multiple-choice question from the main flow, different feedback is given and a thought-provoking question is asked. Then, depending upon the response to this question, a review may be given, an additional question may be presented, or some resulting conclusion is stated followed by transfer back to the original main flow question. If the student answers the main flow question incorrectly on his second attempt, he is given a review.

Key to Flowchart - Feedback Adjusted to Student

1. Start
2. Setting of counter n to one, two, or three corresponding to feedback type on the basis of some judgment as to the student's personality or achievement
3. Presentation of a question; student responds
4. Was response correct?
5. Should feedback 1, telling the student he is correct, be given; that is, is counter n equal to one?
6. Feedback 1, telling the student he is correct, is given
7. Should feedback 2, telling the student he is correct, be given; that is, is counter n equal to two?
8. Feedback 2, telling the student he is correct, is given
9. Feedback 3, telling the student he is correct, is given
10. Should feedback 1, telling the student he is incorrect, be given; that is, is counter n equal to one?
11. Feedback 1, telling the student he is incorrect, is given
12. Should feedback 2, telling the student he is incorrect, be given?
13. Feedback 2, telling the student he is incorrect, is given
14. Feedback 3, telling the student he is incorrect, is given
15. Next problem in sequence

Feedback Adjusted to Student

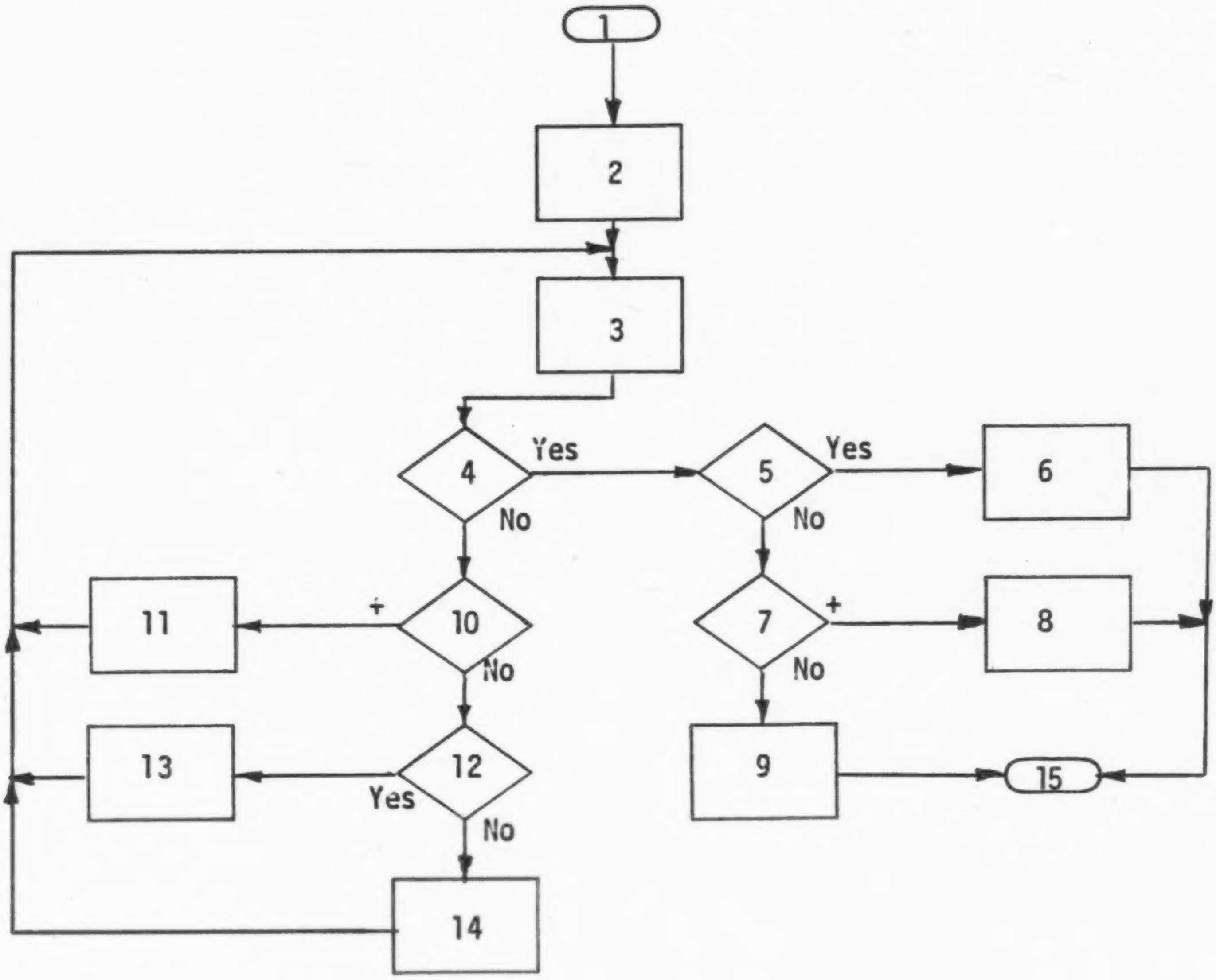

1
2
3
4
Yes
No
5
Yes
No
6
7
+
No
8
9
15
10
+
No
11
12
Yes
No
13
14

Fig. 27. Feedback adjusted to student.

Key to Flowchart - Varying Feedback for Each Response Attempt

1. Start and initialization of the counter used to record number of response attempts to this problem (counter (n)
2. Question is presented and student responds
3. Counter n is incremented by one
4. Did student give the correct answer?
5. Additional answer analysis instructions and appropriate feedback
6. Does counter n contain 1?
7. Feedback 1, for response correct on first attempt, is given
8. Does counter n contain 2?
9. Feedback 2, for response correct on second attempt, is given
10. Does counter n contain 3?
11. Feedback 3, for response correct on third attempt, is given
12. Feedback 4, for response correct on fourth or later attempts, is given
13. Next problem

Varying Feedback for Each Response Attempt

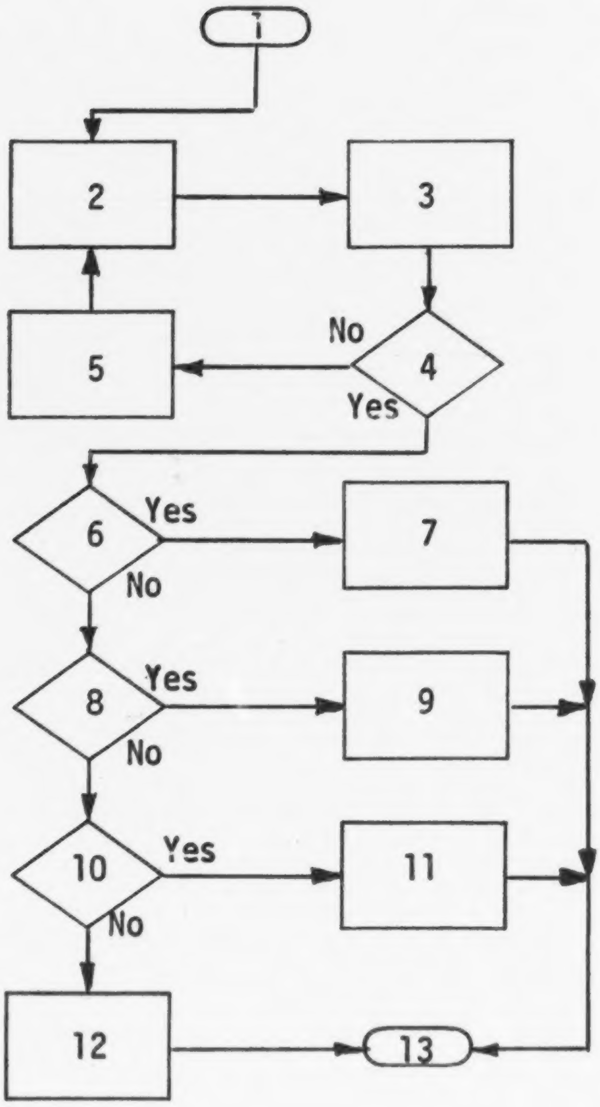

1
2
3
4
No
Yes
5
6
Yes
No
7
8
Yes
No
9
10
Yes
No
11
12
13

Fig. 28. Varying feedback for each response attempt.

The main flow question used in this flowchart appeared in a programed textbook by Heimer and others (1963).

At any time during the multiple-level question, if the student does not select from the stated choices, he is branched to a special routine to inform him of this condition and is given a chance to respond to the question again. Also, after each special review, a branch is made back to the original question (see Figure 29).

Editing Student's Response

It would be unreasonable to assume that each student will type the correct answer in one definite sequence of characters. Since the computer records by characters, it may be necessary, in order to eliminate a possible source of confusion, to delete irrelevant characters from a student's response prior to analyzing whether it is correct. Several examples of what can be done in computer-assisted instruction are as follows:

1. replace commas and periods with a space or delete specific punctuation marks
2. compress all spaces from the student's response
3. compress multiple spaces into one space
4. replace capital letters with lower case
5. replace an l (el) with a 1 (one)

In addition, words can be replaced with synonyms.

Downshifting response characters and replacing words with numbers. The author specifies that the quantities 12 and 3 appear in the student's answer in that order for the answer to be accepted as correct, but he wishes to allow the student to input these quantities as words, with or without capital letters, or as numerals. He accomplishes this by editing the response in a manner to delete any shift characters from the student's response and to replace "twelve" with "12" and "three" with "3," and then testing the student's answer for the presence of 12 and 3 in order (see Figure 30).

Replacing words in student's response with synonym. Often a word in a student's response is acceptable as correct even though misspelled. The example which follows illustrates one way that the student's response may be

Key to Flowchart - Multiple-Level Question[11]

1. Display question:

   When we write $\sqrt{x-2}$, it is understood that $x-2$ ___ 0.

   a. $\geq$ b. $\geq$ c. $=$ d. $\leq$

2. Did student select b? If so, go to 3; otherwise, go to 5
3. Give feedback: You are correct
4. Next problem
5. Has student answered the question from the main flow (item 1) incorrectly twice? if so, go to 6; otherwise go to 8
6. Give feedback that student has answered incorrectly once again and branch to a special review
7. Special review on why $\sqrt{x-2}$ implies that $x-2 \geq 0$
8. Did student select a? if so, go to 9; otherwise, go to 10
9. Give feedback: Your answer is partially correct. $x-2$ is defined when $x-2 > 0$. Is $\sqrt{x-2}$ defined when $x-2 = 0$? (Answer yes or no.) Go to 27
10. Did student select c? if so, go to 11; otherwise, go to 12
11. Give feedback: Your answer is partially correct. $\sqrt{x-2}$ is defined when $\sqrt{x-2} = 0$. Is $\sqrt{x-2}$ defined when $x-2 > 0$? (Answer yes or no.) Go to 33.
12. Since the student gave d as his choice, he is asked: Is $\sqrt{x-2}$ defined when $x-2 = 0$? (Answer yes or no.)
13. Did student answer yes? if so, go to 14; otherwise, go to 15
14. Feedback that student is correct is given. Go to 16
15. Has student answered the question in item 12 incorrectly twice? if so, go to 7; otherwise, go to 29
16. Student is asked: Is $\sqrt{x-2}$ defined when $x-2 > 0$? (Answer yes or no.)
17. Did student answer yes? if so, go to 18; otherwise, go to 19
18. Feedback is given that student is correct. Go to 25
19. Has student had a prior opportunity to answer the question in item 16? if so, go to 20; otherwise, go to 21
20. Special review on why $\sqrt{y}$ is defined when $y > 0$
21. Student is told that he is incorrect and is given the additional feedback:

    Recall that when we write $\sqrt{y}$, it is understood that $y \geq 0$.
    If $y = x-2$, then by our agreement, if we write $\sqrt{x-2}$, then
    $x-2 = 0$ or $x-2$ __ 0.

    a. $<$ b. $=$ c. $>$ d. none of these

22. Did the student answer c? if so, go to 23; otherwise, go to 26

23. Feedback is given: Correct. $\sqrt{x-2}$ is defined for $x-2 > 0$. Go to 24
24. Did student come to the question in item 21 from a wrong answer to item 16? if so, go to 16; otherwise, go to 25
25. Additional feedback is given: Thus, $\sqrt{x-2}$ is defined when $x-2$ is non-negative. Now try again to answer the original question (item 1)
26. Feedback is given: No. The correct answer is > . If we write $r \geq s$, we mean $r > s$ or $r = s$. Go to 24
27. Did student select yes? If so, go to 28; otherwise, go to 29
28. Feedback, "Right," is displayed. Go to 25
29. Feedback is displayed: Incorrect. Recall that when we write $\sqrt{y}$, it is understood that $y \geq 0$. If $x-2 = 0$, then $x-2 = \sqrt{0}$ and $\sqrt{0}$ = ?

    a. 0 b. 1 c. 2 d. none of these
30. Did student answer a? if so, go to 31; otherwise, go to 35
31. Feedback is given: Correct. Thus, $\sqrt{x-2}$ is defined when $x-2$ is non-negative. Now try again to answer the question. Flow goes to item 32
32. Did the student come to this question after answering the original question with the incorrect choice d? if so, go to 12; otherwise, go to 1
33. Did student answer yes? if so, go to 34; otherwise, go to 21
34. Feedback is given that student's response is correct. Go to 25
35. Feedback is given: No. $\sqrt{0} = 0$ so $\sqrt{x-2} = 0$. Thus, $\sqrt{x-2}$ is defined when $x-2 = 0$. Go to 32

---

[11] From Penn State's course segment *Demonstration in Mathematics*, for National Conference on Computer-Assisted Instruction, The Pennsylvania State University, University Park, Pa., September 24-26, 1968; IBM 1500; authors: Ralph Heimer, Paul Klein, Robert Hostetler, Carol Dwyer.

Multiple Level Question

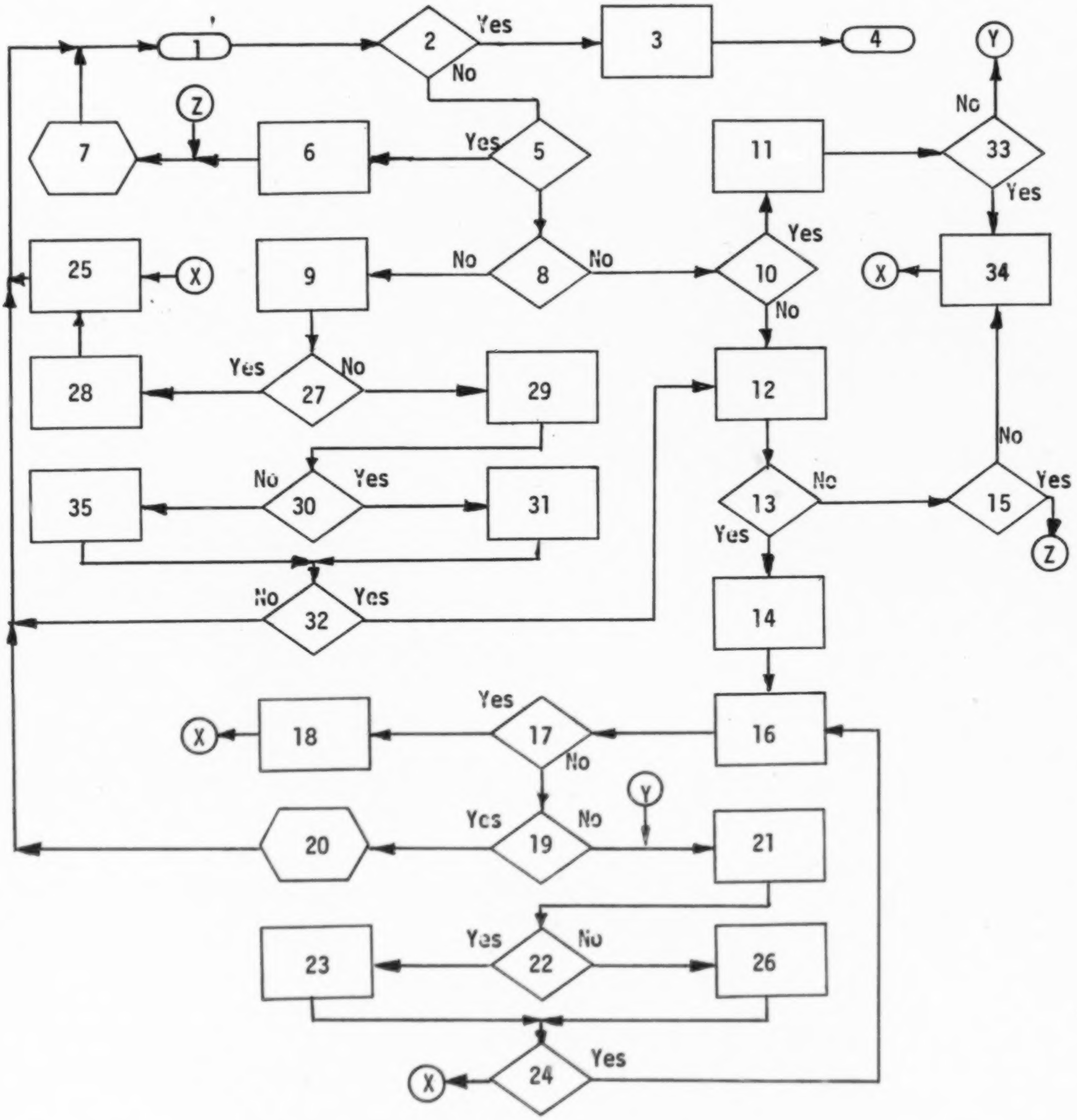

1
2
Yes
No
3
4
Y
Z
7
6
Yes
5
11
No
33
Yes
25
X
9
No
8
No
10
Yes
No
X
34
28
Yes
27
No
29
12
No
35
No
30
Yes
31
13
No
15
Yes
Yes
Z
No
32
Yes
14
Yes
17
No
18
X
16
Y
Yes
19
No
20
21
Yes
22
No
23
26
24
Yes
X

Fig. 29. Multiple level question.

Key to Flowchart

Downshifting Response Characters and Replacing Words with Numbers

1. Start
2. Display question: In our system of measurement, we use the foot and the yard. There are _____ inches in 1 foot and _____ feet in 1 yard
3. Student responds to question
4. Response is edited with functions. That is, upper case letters are replaced with lower case; "12" replaces "twelve;" "3" replaces "three"
5. The integer which appears first in the response is placed in counter a; the integer which appears second is placed in counter b
6. Does counter a contain 12? if yes, go to 7; if no, go to 9
7. Does counter b contain 3? if yes, go to 8; if no, go to 9
8. Feedback that answer is correct
9. Feedback given because of incorrect answer: There are 12 inches in 1 foot and 3 feet in one yard
10. Next problem

Downshifting Response Characters and Replacing Words with Numbers

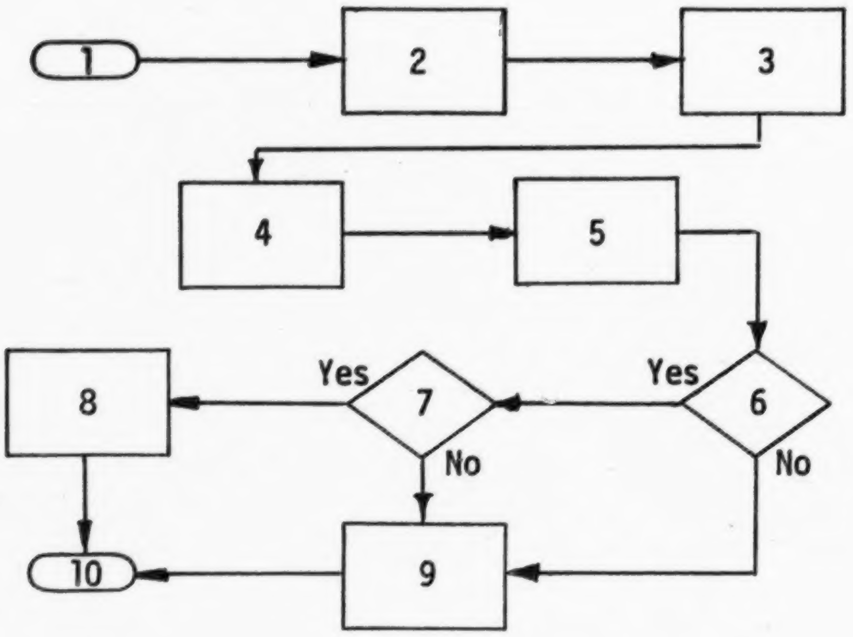

1
2
3
4
5
Yes
6
No
Yes
7
No
8
9
10

Fig. 30. Downshifting response characters and replacing words with numbers.

edited so that a specific word in his response is changed to the most acceptable version of the word (antihelix), and then his response is tested for the presence of three words (lower, crus, antihelix) in order as separate words (see Figure 31).

Responses Checked for Key Parts

When one thinks of the number of possible combinations that a student could type a set of three correct words, he realizes that it would be quite a task if in each multiple-word response the various versions of the correct answer had to be listed! In CAI, functions can be used to scan the student's response for the words of the correct answer, evaluate the number correct, and inform the student which items are correct.

Testing for specific words in student's response. Since many varieties of both correct and incorrect responses can be made by students, it is often desirable to check for specific "key" words in the response and give feedback based on the number of words which matched the correct response. In this example, if at least six of the seven words are matched, the student is told he is correct and is branched to the next problem. If from one to five words are matched, the student is informed as to which words he had correct. If no words were matched, the student would be branched to a review section (see Figure 32).

Checking response for specific character strings. This section describes a routine which is designed to test a student's response for specific character strings (partial words), as opposed to complete key words. If any of the strings are found, the student's correct words (i.e., those words containing acceptable strings of letters) are fed back to the student (see Figure 33).

Multiple-Part Responses

A question often asked about CAI is whether or not the system can handle responses consisting of several parts such as sentences or mathematical equations. The answer is affirmative, and with the capability to write new functions and add them to the system, the possibilities are almost limitless. Student-constructed equations and complex numbers can be analyzed for correctness.

Key to Flowchart - Replacing Words in Student's Response with Synonym[12]

In this example, the student is asked to identify a portion of the pinna marked on a plaster model of the human ear.

1. Start
2. Question is presented: "What is the name of part C?" Student is given opportunity to respond
3. Editing is done to change a word in the student's response to the most acceptable version, i.e., anthelix, anti helix, anti-helix, anti -helix, anti- helix, and anti - helix are edited to antihelix
4. The correct response, lower crus antihelix, is compared with the student's response. A test is made to determine whether three words in the student's response were correct. Were three words correct?
5. Feedback for correct response is displayed: Your answer is correct
6. Next problem
7. A test is made to determine whether one or more words in the student's response were correct. Were one or more words correct?
8. Feedback for partially correct response is displayed: Your answer is partially correct. Try again
9. Feedback for totally unrecognizable response is given: Your answer is incorrect. Find the correct answer on your handout and type it.

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[12] From Penn State's course segment Audiology, Project No. 5-1194, IBM 7010 or 1410; authors: Bruce M. Siegenthaler and Jeffrey Katzer.

Replacing Words in Student's Response with Synonym

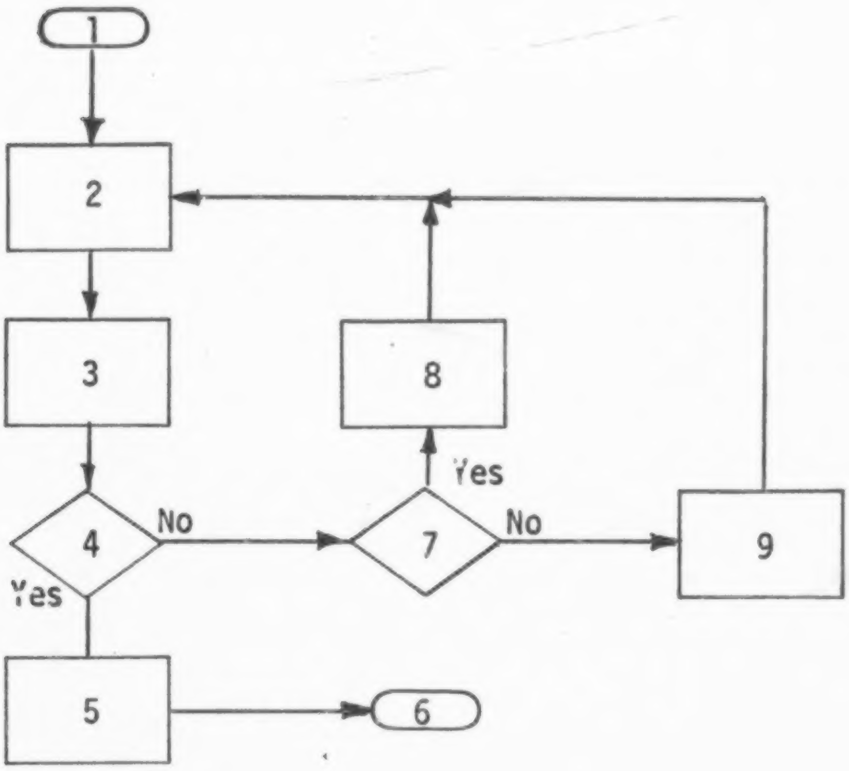
1
2
3
4
No
Yes
5
6
7
Yes
No
8
9

Fig. 31. Replacing words in student's response with synonym.

Key to Flowchart - Testing for Specific Words in Student's Response

1. Start
2. Problem is presented: Name six of the seven colors of the spectrum.
3. The response is checked for correct words (red, orange, yellow, green, blue, indigo, violet). Is the number of matched words equal to or greater than 6?
4. Feedback for correct answer is given: You have the answer entirely correct. Very good.
5. Next problem
6. Is the number of matched words greater than or equal to 1?
7. The correct words from student's response are shown to him
8. Feedback for partially correct response is given: The list above indicates which colors you have correct. Give another answer including these you now have correct
9. Unrecognized response noted
10. Feedback for answer with no correct words given: You aren't doing very well. It appears you need a review.
11. Review of concepts from which branch will be made back to current problem

Testing for Specific Words in Student's Response

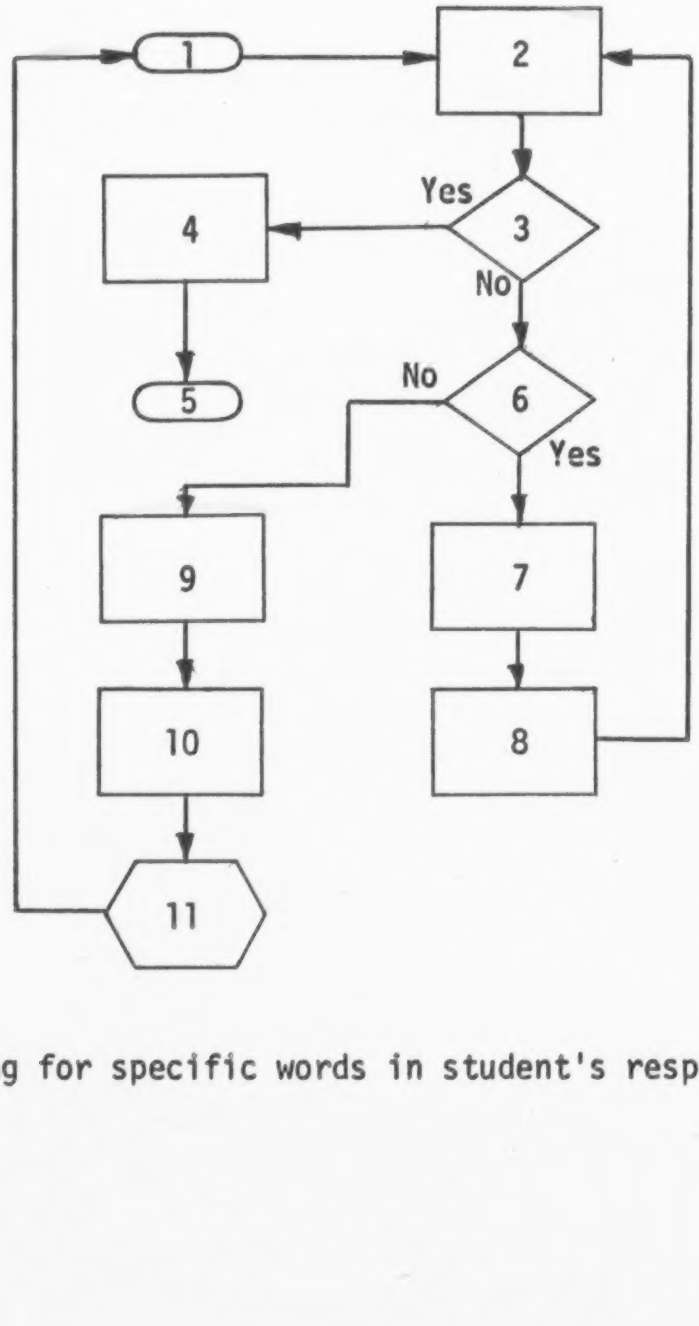
1
2
Yes
3
No
4
5
No
6
Yes
9
7
10
8
11

Fig. 32. Testing for specific words in student's response.

Key to Flowchart - Checking Response for Specific Character Strings

1. Start
2. Display question: What are the three fundamental particles in an atom?
3. Student responds to the question
4. Test for key strings (i.e., "prot," "neut," "elect") to see how many match the correct strings; if all are found, go to 5; if one or more are found, go to 7; and if none are found go to 9
5. Display feedback for correct response
6. Next section of course
7. Edit student's response so that only the words containing correct strings appear
8. Display the edited response to indicate to the student which words were correct and give the message that the answer is partially correct and the student is to try again; go to 3
9. Indicate the answer is completely wrong and go to 3

Checking Responses for Specific Character Strings

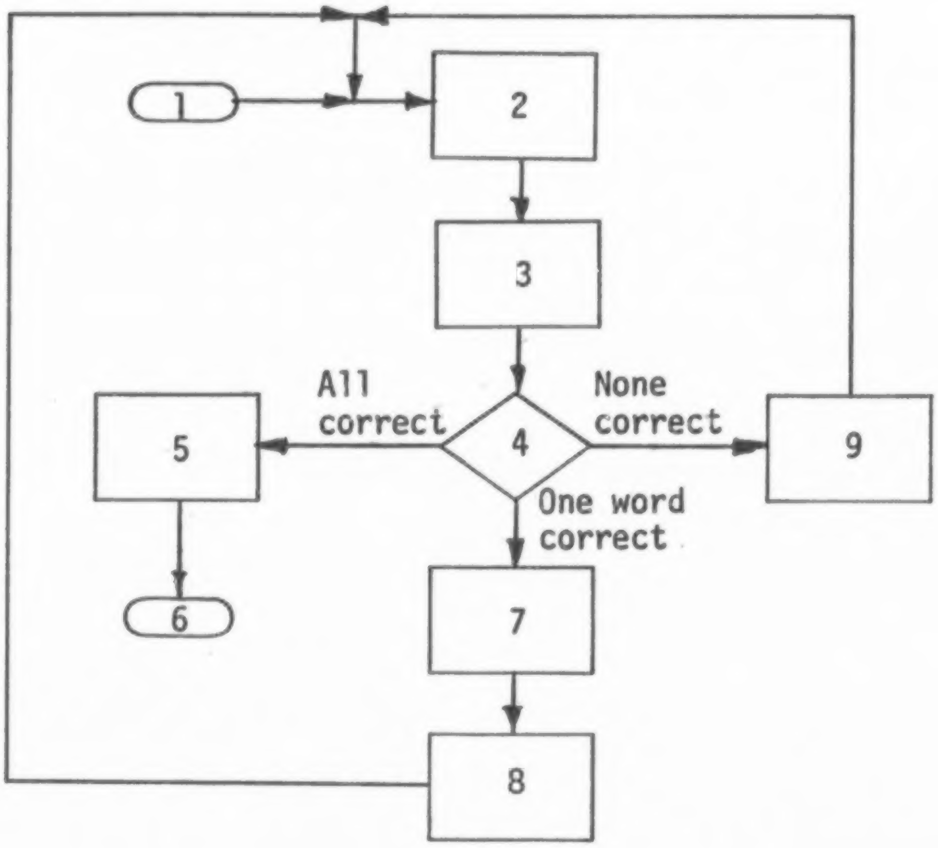
1
2
3
All correct
4
None correct
5
9
One word correct
6
7
8

Fig. 33. Checking responses for specific character strings.

Creating a response by selecting its parts. A creative approach from the student's viewpoint can be used in the construction of mathematical open sentences (i.e., equations with unknown quantities). Given the mathematical characters □, =, +, 3, and 4, the student is asked to construct an open sentence using each of the items once. As an item is selected, it is excluded from the list so that it may not be used again, thus limiting the number of possible correct solutions.

On the first incorrect response, the student is told that the items do not form an open sentence. On subsequent incorrect responses, he is given a list of correct responses, is asked to construct one of these, and ask the proctor for help if needed (see Figure 34).

Two-part response by student. Often a response includes two parts, each of which should receive specific feedback. In this example each part of the response consists of one word, either oxygen, or hydrogen. Feedback is given indicating which of the words are correct. If the student does not answer the question correctly by the third attempt, he is branched to a review (International Business Machines Corporation, 1968, pp. 43-44, 52), (see Figure 35).

Responses Requiring Ordering

Many questions asked by instructors require more than one word in the response. In addition, in the correct response these words must be in a definite order. CAI has the capability to analyze responses containing several words, letters, numbers, or strings of characters. These key parts may be checked for order, position, and initial words or characters.

Arrangement by student of given items in proper order. The problem for the student in this exercise is to arrange five particles (proton, neutron, electron, atom, and molecule) according to weight and for him to type only the initial letters in the proper order. The author wants the student to be able to enter the letters freely, in upper or lower case and with any reasonable combination of punctuation and spaces between the letters. Also, since he lists the particles, the author anticipates that a student may list the letters, i.e., separate them with carriage returns. Therefore, the author begins by deleting shift-characters, spaces, periods, commas, semi-colns, colns, dashes, and carriage returns from the student's response. He then tests for the

Key to Flowchart - Creating a Response by Selecting Its Parts[13]

1. Start
2. Display the basic set of symbols: □, =, +, 3, 4
3. Give instructions for the problem
4. Student responds by indicating the order of his choices from the given items
5. Is the student's response a valid open sentence construction? if not, go to 8; otherwise, go to 6
6. Give feedback that response was correct and go to 7
7. Next phase of instruction
8. Is this the student's first mistake? if so, go to 9; otherwise go to 10
9. Feedback: The items do not form an open sentence in the order chosen. Answer again.
10. Display all possible valid constructions of open sentences using the given elements; ask the student to type one of these and to request help from the proctor if assistance is needed

---

[13] From Penn State's course segment General Mathematics, U. S. Office of Education through the School District of Pittsburgh, prime contract Grant No. OEG-0-8-055230-3479, Project No. 5523, IBM 1500 System; authors: Roland Lazzaro, John McNear.

Creating A Response by Selecting Its Parts

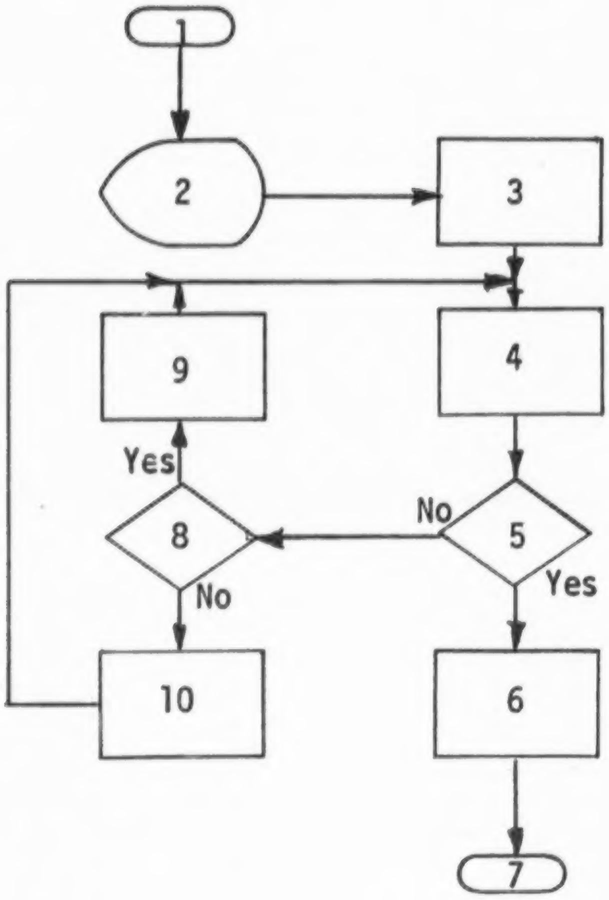
1
2
3
4
5
No
Yes
6
7
8
Yes
No
9
10

Fig. 34. Creating a response by selecting its parts.

Key to Flowchart - Two-Part Response by Student

1. Question is presented: What are the two elements of water?
2. Student is allowed to respond with two separate words
3. Increment counter keeping track of number of responses to this question; initialize counter keeping track of which words are given correctly
4. Does student's response include the word "oxygen?"
5. Indicate to the student that "oxygen" is correct
6. Increment by 2 the counter keeping track of which words appeared in the response
7. Does the student's response include the word "hydrogen?"
8. Indicate to student that "hydrogen" is correct
9. Increment by 1 the counter keeping track of which words appeared in the response
10. Does the counter keeping track of which words appeared in the student's response contain 3?
11. Next problem
12. Has student made three attempts to answer the question?
13. Tell the student that the correct response is oxygen and hydrogen and indicate to the student that he will receive a review
14. Review from which student will be branched to the beginning of the question set
15. Give him feedback that the response is incorrect; ask him to answer again, giving both elements correctly

Two-Part Response by Student

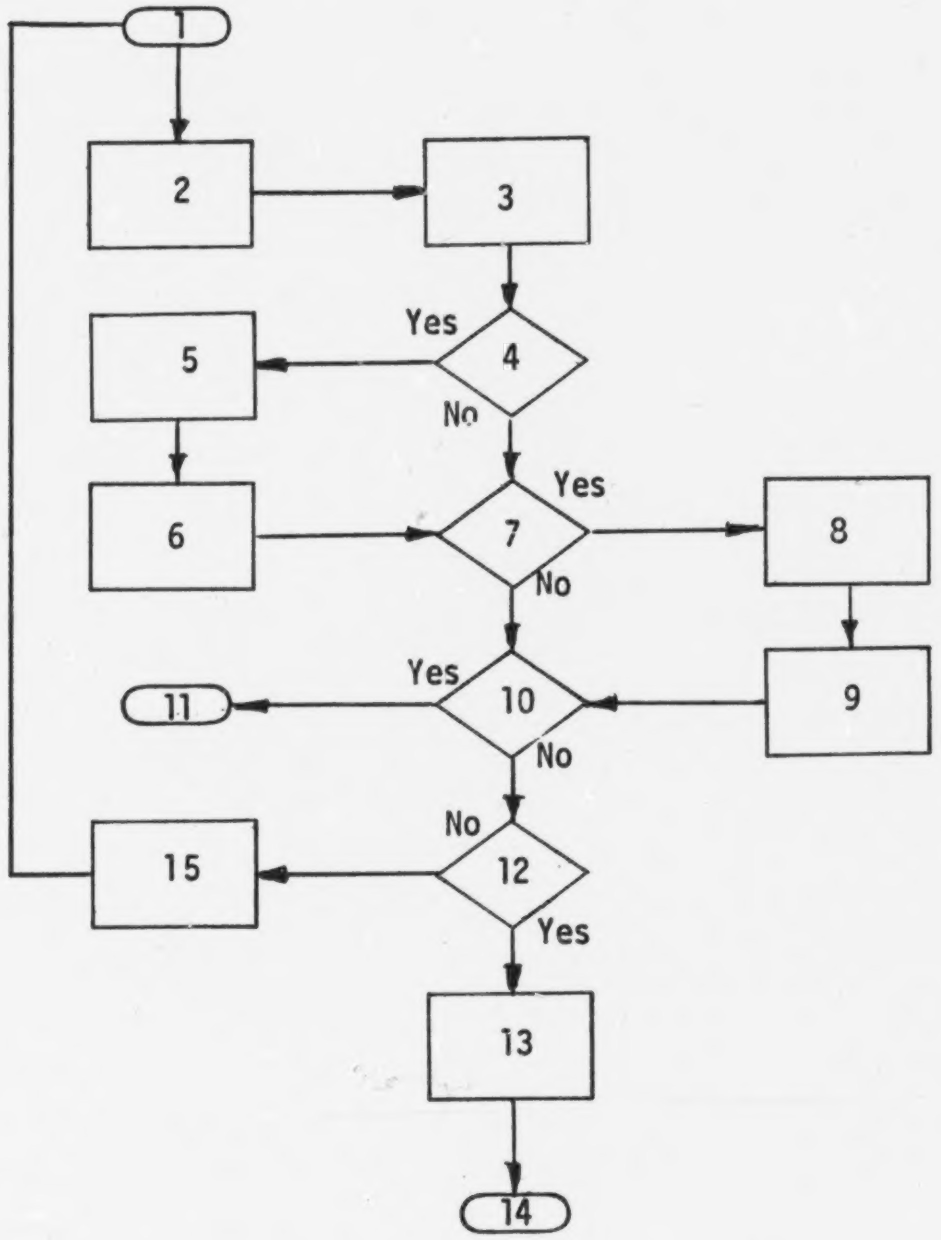
1
2
3
Yes
4
5
No
6
Yes
7
8
No
Yes
11
10
9
No
No
15
12
Yes
13
14

Fig. 35. Two-part response by student.

correct answer: *manpe*. If this fails, the author tests for the presence of any of the other 21 letters of the alphabet and the numbers 1, 2, 3, 4, 5. If one or more extraneous letters or numbers are found, the student is told to type only the initial letters and to answer again.

At this point in the processing, if one of the letters *manpe* is found, it is not because the student entered a word such as "neutron." The author therefore tests for the presence of at least one of the letters. If at least one is found, the student gets a feedback which types the letter(s) he had in the correct order and types dashes for the letter(s) which he omitted or had out of order. For example, if the student's answer is *mpnea*, the feedback is: *ma---*.

If the student's answer does not contain at least one of the five letters, he receives feedback designed for an unrecognizable response (see Figure 36).

Analyzing a response containing ordered words. Many times a significant part of the response is the order in which the words of the response are given. An example would be a request to identify the four seasons of the year beginning with the season of the month of January.

In this example, for the student's answer "fall winter spring summer," feedback would be given in the form "winter spring summer ----" with the statement that the dashes indicate an omission or improper order of the season.

In order to eliminate the resulting confusion if the word autumn would be used in place of fall, prior to checking the response, "autumn" would be edited to "fall" (see Figure 37).

Numerical Responses

Many types of numerical responses may be analyzed in a CAI system. Responses may be checked precisely or to determine whether they fall into a specified range. Several numbers may be checked simultaneously; the numerator and denominator of fractions may be checked individually.

Testing for a numerical response within a specified range. An author may want to accept any response in which the integer portion of the number in a response is correct, regardless of the value of the decimal places or the nature of the text typed along with the number.

Key to Flowchart - Arrangement by Student of Given Items in Proper Order[14]

1. Start; initialize to zero the counter in which number of responses is kept
2. Show the proper image on the image projector and display the statement: The proton is much heavier than the electron. The neutron is about the size of the proton and electron combined. Arrange the particles according to weight from the largest to the smallest. Type only the first letter of each word.
3. Display the list: proton, neutron, electron, atom, molecule
4. Student is given time to type his response
5. Punctuation and spaces are edited from student's response
6. Is student's response "*manape*?"
7. Give feedback: Correct: molecule, atom, neutron, proton, electron
8. Next problem
9. Increment by 1 the counter in which number of responses to the question is recorded
10. Has student responded more than four times?
11. Give proctor message asking proctor to assist student or give a review
12. Does student's response contain extraneous letters or numbers?
13. Display: Type only the initial letter of each particle (in order)
14. Is at least one of the letters in the student's response in the correct order?
15. Give feedback indicating which letters were placed in proper order
16. Is this the first unrecognized response?
17. Display: Reread the paragraph above and consider the relative weight of each particle. Then type the initial letter of each particle from the largest to smallest
18. Is this the second unrecognized response?
19. Feedback: The molecule is the largest. An m should be your first letter. Try again.
20. For all additional unrecognized responses feedback is as follows: Hint--Each atom is composed at least of one electron, proton, and neutron. Answer once again.

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[14] From Penn State's course segment Atomic Energy. Project No. 5-85-074 IBM 7010 or 1410; author: David Gilman.

Arrangement by Student of Given Items in Proper Order

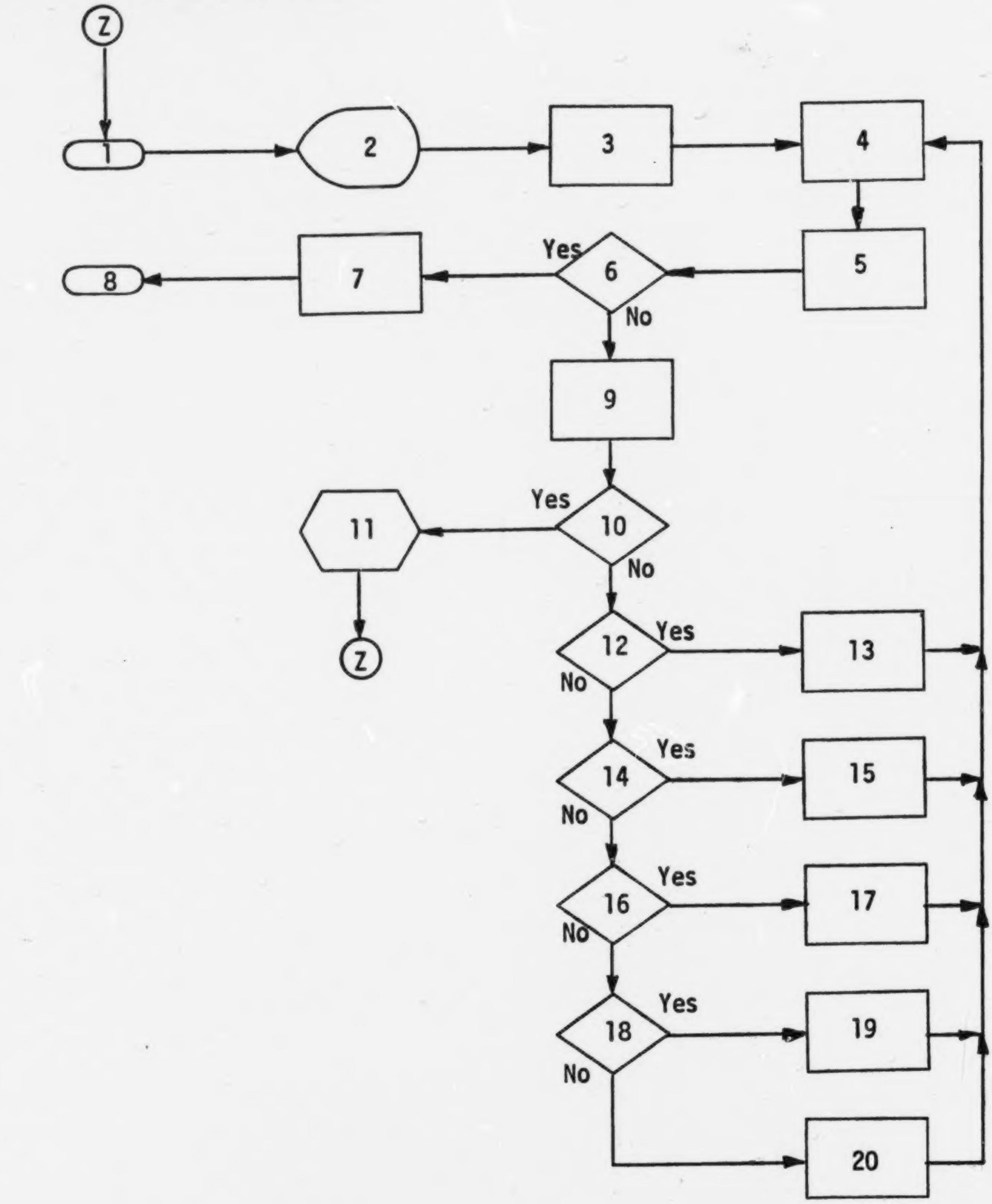
Z
1
2
3
4
5
Yes
6
No
7
8
9
Yes
10
No
11
Z
12
Yes
No
13
14
Yes
No
15
16
Yes
No
17
18
Yes
No
19
20

Fig. 36. Arrangement by student of given items in proper order.

Key to Flowchart - Analyzing a Response Containing Ordered Words

1. Start
2. Presentation of question: What are the four seasons of the year, starting with the season in which January is?
3. Student responds
4. Any appearance of "autumn" in the student's response is edited to "fall."
5. Does the response contain "winter spring summer fall" in proper order?
6. Give feedback that the response is correct and all seasons are in the proper order
7. Next problem
8. Does the student's response contain at least one correct word?
9. Give feedback as to which words are in the proper order and ask the student to answer again
10. Has the student responded with an unrecognizable response two times?
11. Remedial instruction on the seasons of the year
12. Give feedback that the response is totally incorrect and the student should try once more to answer the question correctly

Analyzing a Response Containing Ordered Words

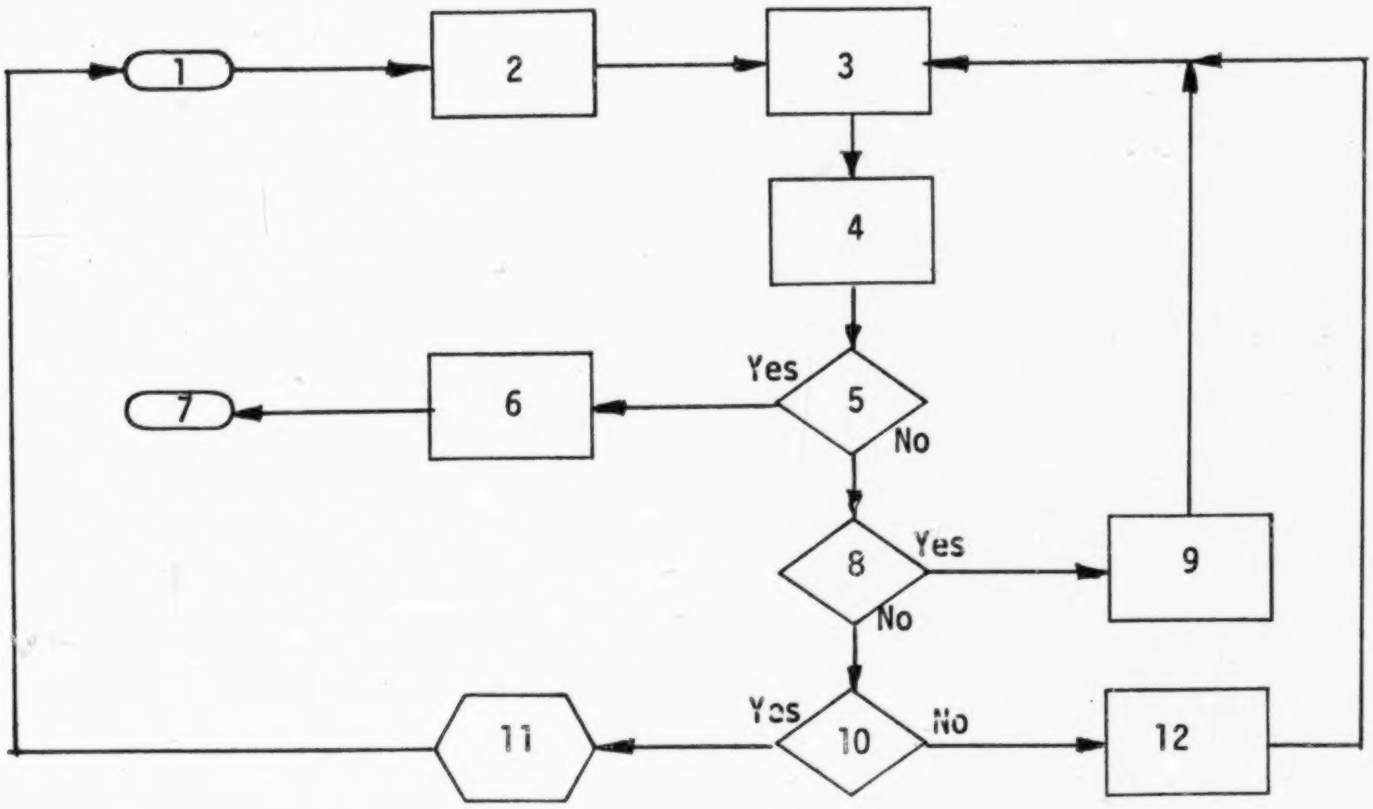
1
2
3
4
Yes
5
No
6
7
8
Yes
No
9
Yes
10
No
11
12

Fig. 37. Analyzing a response containing ordered words.

Proper coding makes it possible to pick a numerical field from a response, convert it to an integer, and store it in a specific counter. The contents of the counter are then compared with the correct response to test whether the student's response was acceptable.

In the example below, the integer is extracted from the response. If the response is exactly correct (5.3), the student will see the correct answer feedback. If the student is almost correct (5.0 to 5.9), he is told the correct response and continues on. If his response does not include the correct integer portion, he is branched to a review (see Figure 38).

Testing for a precise numerical response. Let us assume in this example that the desired numerical response must be precise to nearest tenth. The student is allowed to respond any number of times and at each response he is told whether his numerical response is too high or too low, and as the range of his response from the precise response is decreased, the feedback gives some encouragement such as "You are very close." (see Figure 39).

Key to Flowchart - Testing for a Numerical Response within a Specified Range[15]

1. Start of problem
2. Problem is presented: Measure line a on the handout. Give your answer in centimeters
3. Student is given a chance to respond
4. Did response match correct answer: 5.3?
5. Feedback for correct answer: Correct
6. The integer portion of the first numerical field is picked out from the response and placed in a counter
7. Does the counter contain 5?
8. Feedback for answer within acceptable range: Correct. The answer is 5.3 and you are close enough to it
9. Feedback for unacceptable answer is displayed. No, there are 5 whole centimeters plus 3 tenths of a centimeter. Let's try a review
10. Pause so that student can measure line a again
11. Special review on measurement in the metric system
12. Next problem

---

[15] From Penn State's course segment Metric System of Measurement. Project No. 5-85-074, IBM 7010 or 1419; author: David Gilman.

Testing for a Numerical Response within a Specified Range

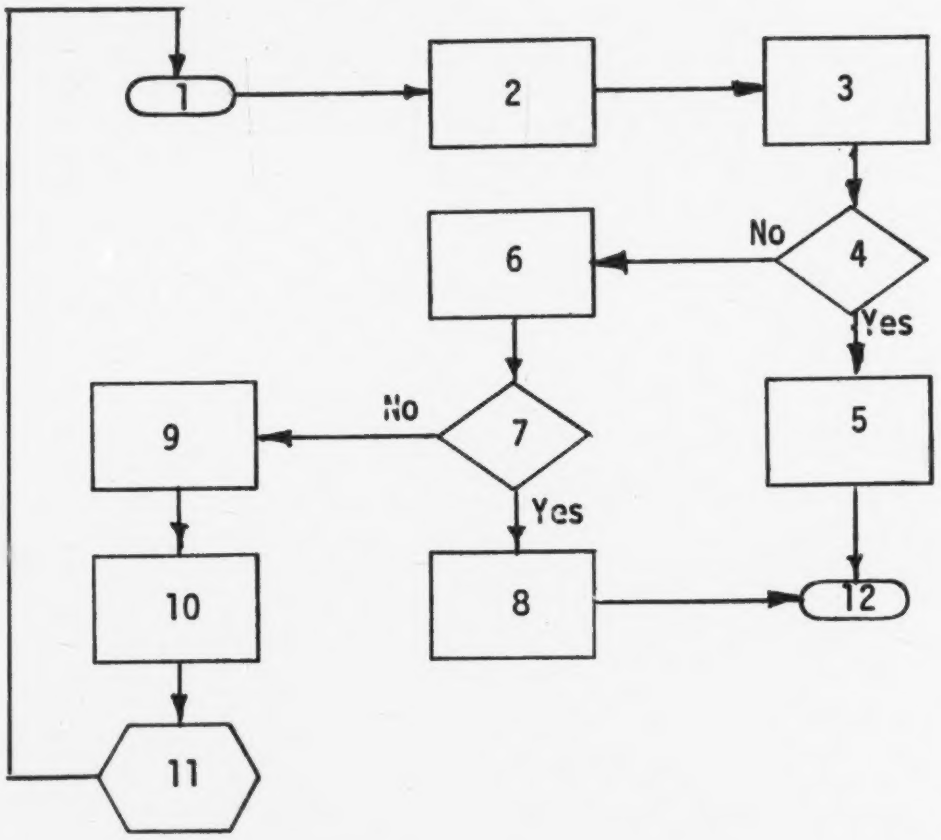
1
2
3
No
4
Yes
5
6
No
7
Yes
8
9
10
11
12

Fig. 38. Testing for a numerical response within a specified range.

Key to Flowchart - Testing for a Precise Numerical Response

Assume that the desired response is 23.7 or between 23.69 and 23.71.

1. Question is presented
2. Student responds
3. Is response between 23.69 and 23.71?
4. Give feedback that response is correct and go to 5
5. Next question
6. Is response between 23.6 and 23.8?
7. Give feedback that student's response is "Extremely close but" and go to 12
8. Is response between 23.0 and 24.0?
9. Give feedback that student's response is "Very close but" and go to 12
10. Is response between 20.0 and 30.0?
11. Give feedback that student's response is "Quite close but" and go to 12
12. Is response less than or equal to 23.69?
13. Give feedback "response is too low."
14. Is response greater than or equal to 23.71?
15. Give feedback "response is too high."
16. If student reaches this point, he has not typed a number so he is told to type a number

Testing for a Precise Numerical Response

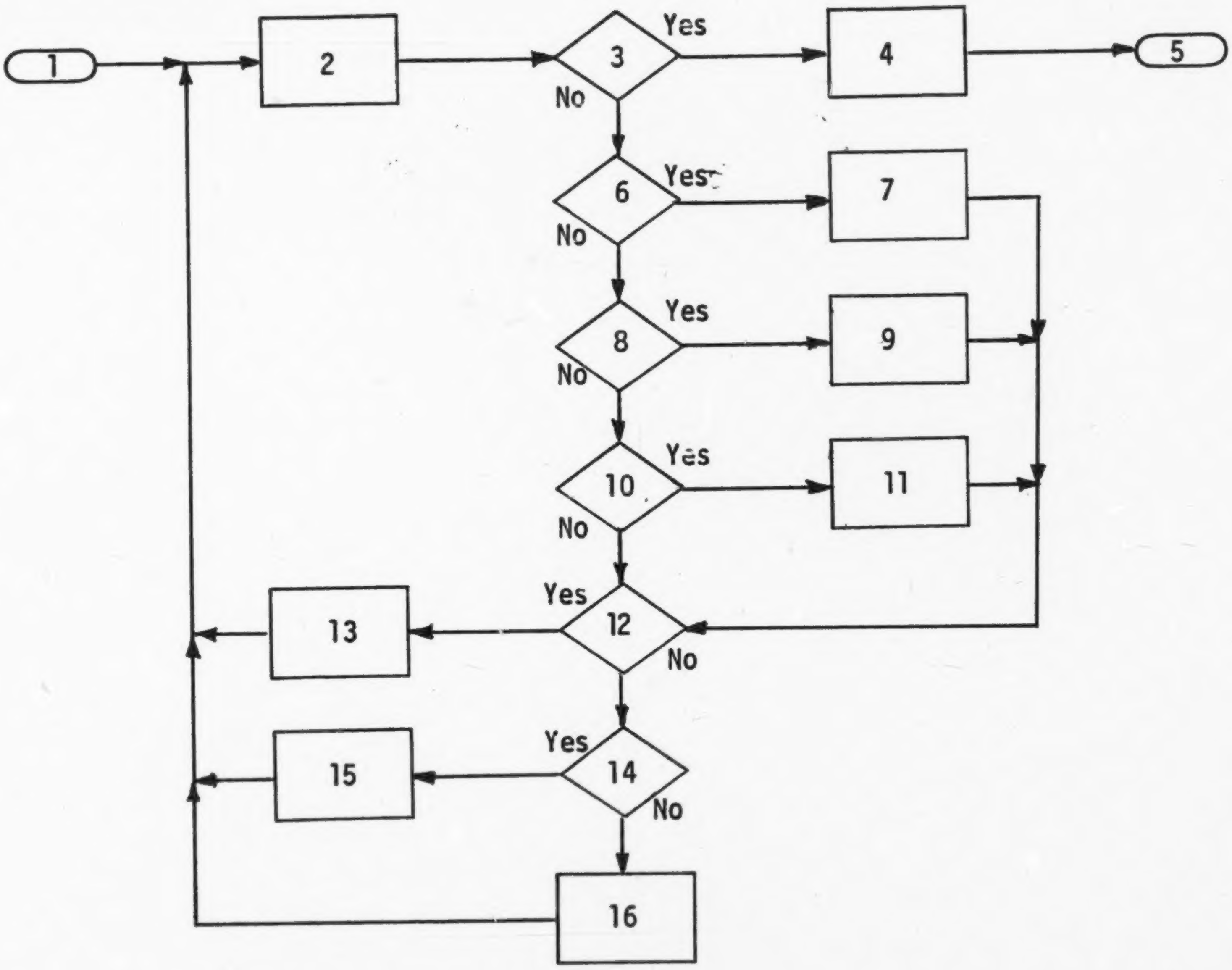
1
2
3
Yes
No
4
5
6
Yes
No
7
8
Yes
No
9
10
Yes
No
11
12
Yes
No
13
14
Yes
No
15
16

Fig. 39. Testing for a precise numerical response.

CHAPTER VIII

DISSEMINATION

Dissemination activities of the CAI Laboratory have been extensive and have varied in form. Fellowships and graduate assistantships have been but one phase of what we see as an ongoing process of training others in the potential of computer assisted instruction in education. New methodologies, new curricula and new educational strategies do not just happen. Innovations must be developed and communicated through as many avenues as possible in order to overcome the great inertia in educational processes. Individuals trained in computer-assisted instruction can influence the course of educational change.

Information about our CAI activities in technical education have been disseminated through demonstrations to individuals from the United States and representatives from foreign countries. Graduate and undergraduate classes have toured the Laboratory facilities and have learned about the potentials of CAI in the coming years. Samples of this information for selected periods is summarized in the tables that follow.

The reports, journal articles, and speeches dealing with the CAI Laboratory are given in the sections that follow. Again it is easily seen that these formal activities have been many and varied and have reached large numbers of professional educators.

A film entitled "Sign On/Sign Off" was designed to give the basic idea of how a computer simulates a tutor. The film describes the equipment and objectives of CAI and is available from the Audio-Visual Library of the University (16mm; 24 minute; sound; color).

Table 6

Organized Dissemination Activities
by CAI Laboratory Personnel
May 1, 1967 through June 30, 1968

Date(s)	Participant(s)	No. in Audience	Event	Location
5/26/67	Mitzel, H. E.	45	Center for Cooperative Research With Schools	Penn State
6/21/67	Mitzel, H. E.	60	American Society for Engineering Education Annual Meeting	East Lansing, Michigan (Michigan State)
7/1/67 to 7/20/67	Mitzel, H. E.	1000	National Seminar on Innovation Sponsored by I.D.E.A. The Action-Oriented Division of the Chas. F. Kettering Foundation and USOE	Honolulu, Hawaii
7/26/67	Mitzel, H. E.	100	Computer Summer Workshop	West Point, New York
8/15/67	Igo, R. V.	50	ENTELEK Workshop	Harvard Univ., Cambridge, Mass.
8/8/67	Mitzel, H. E., Brandon, G.	200	National Educational Media Seminar in Vocational and Technical Education	Columbus, Ohio
10/3/67	Mitzel, H. E.	40	Training program on Management Development for Health Agency Personnel, Hospital Administrators, etc.	Penn State
10/6/67	Mitzel, H. E., Hall, K. A. Johnson, D. Riedesel, A.	75	USOE Demonstration Center	Washington, D. C.

10/27/67	Mitzel, H. E. Hall, K. A.	125	Phi Delta Kappa Meeting, Alpha Chapter	Penn State
10/27/67	Farr, H. L. K.	45	Pennsylvania Council of Teachers of English, 11th Annual Conference	Penn State
11/13/67	Mitzel, H. E.	200	Convocation of Educational Research Association of New York State	Albany, New York
11/9/67	Mitzel, H. E. Hall, K. A. Brown, B. R.	20	Psychologists from Penn State's Commonwealth Campuses	Penn State
2/22/68	Mitzel, H. E. Hall, K. A. Dwyer, C. Knull, D.	35	Faculty Development Institute	Penn State
3/28/68	Hall, K. A.	450	NEA Department of Audio Visual Inst.	Houston, Texas
4/18/68	Hall, K. A.	150	National Society of Programed Inst.	San Antonio, Texas

Table 7

Visitors to CAI Laboratory
May 1, 1967 through April 30, 1968

Number in groups	919
Individuals	73
Total	992

Countries Represented:

Australia

Canada

England

Netherlands

Sudan

Table 8

Summary
1410 Student Terminal Usage
May 1, 1967 through April 30, 1968

Use	Number	Hours	Avg. Per. Month
Students	788*	1,163.37	96.95
Staff		330.65	27.55
Demonstrations		109.44	9.12
A/V Testing		7.21	.60
Equipment Testing	___	9.59	.80
Testing	788	1,620.26	135.02

*Investigations	694	1,088.37
Other Subjects	94	75.00
	788	1,163.37

Table 9

1500 System Usage
February 1, 1968 through April 30, 1968

System Usage	No. of Hours	Avg. Per. Month
Author/Student	1,336.95	445.65
Demonstrations	58.03	19.34
Systems Work	124.00	41.33
Preventive Maintenance	26.00	8.67
Total	1,544.98	514.99

THE PENNSYLVANIA STATE UNIVERSITY

College of Education
201 Chambers Building
University Park, Pennsylvania 16802

Computer Assisted Instruction Laboratory

CAI
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Semi-Annual Progress Report (70 pp.) June 30, 1967

No. R9 Mitzel, Harold E., and Brandon, George L. Project No. O.E.-5-85-074

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